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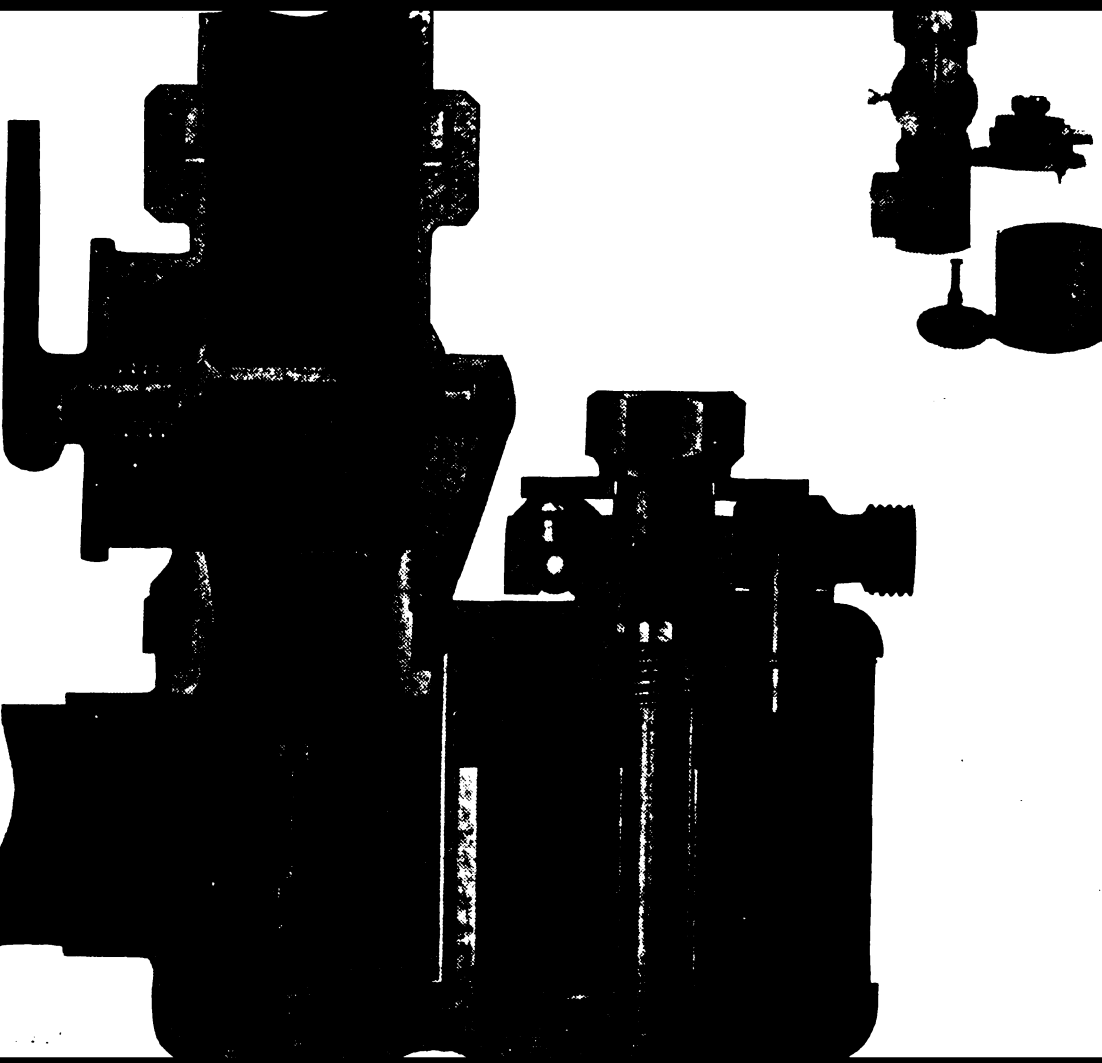

# *Transactions*

Society of Automobile Engineers (U.S.)

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# THE SOCIETY OF AUTOMOBILE ENGINEERS

# 1913 TRANSACTIONS

## PART II

## VOLUME VIII

Comprising Papers and Reports and Discussion of Same Presented at the June, 1913, Meeting of the Society, and some Papers and Discussions Presented during 1912 and 1913 at Meetings of Sections of the Society.

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# The
# Society of Automobile Engineers

Founded 1905 Incorporated 1906

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| 1909 | HENRY HESS |
| 1910 | HOWARD E. COFFIN |
| 1911 | HENRY SOUTHER |
| 1912 | HENRY F. DONALDSON (deceased) |
| 1912 | HERBERT W. ALDEN |

The Society shall not be responsible for statements or opinions advanced in papers or discussions at its meetings * * *

—(*Constitution, paragraph 59.*)

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# CONTENTS*

PAGE

ALUMINUM ALLOYS.
C. E. Cox ..... 324
AN IDEAL AUTOMOBILE PLANT.
Henry M. Leland ..... 297
ATMOSPHERIC READINGS IN MOTOR TESTING.
Ferdinand Jehle ..... 328
BALL AND ROLLER BEARINGS DIVISION REPORT ..... 2, 64
BIBLIOGRAPHY OF STEEL ..... 41
CARBURETION PROBLEMS.
Arthur B. Browne ..... 192
CHASSIS TESTING APPARATUS.
P. P. Dean ..... 346
COMMERCIAL CAR WHEELS DIVISION, FOURTH REPORT OF ..... 51, 66
DEPRECIATION OF COMMERCIAL AUTOMOBILES.
Charles Wheeler ..... 108
DESIRABLE NUMBER OF GEAR CHANGES.
P. S. Tice ..... 336
ELECTRICAL EQUIPMENT DIVISION REPORT ..... 2, 67
HEAT TREATMENT OF LEAF SPRINGS.
E. F. Lake ..... 248
INSPECTION METHODS.
E. F. Roberts ..... 136
IRON AND STEEL DIVISION, FOURTH REPORT OF ..... 7, 59
JACKSHAFT VERSUS DOUBLE REAR-WHEEL BRAKES.
A. M. Laycock ..... 263
KEROSENE CARBURETION.
P. S. Tice ..... 306
LIST OF SOUVENIRS PRESENTED TO BRITISH GUESTS OF THE SOCIETY ..... 302
LONDON MOTOR OMNIBUS SERVICE.
T. B. Browne ..... 75
LUBRICATING OIL.
Harry Tipper ..... 254
MALLEABLE IRON CASTINGS.
Enrique Touceda ..... 148
MEASUREMENT OF HORSEPOWER.
Prof. W. Morgan and E. B. Wood ..... 110
MOTOR DESIGN FACTORS.
Claude E. Cox ..... 166
MOTOR TRUCK WHEELS.
Arthur J. Slade ..... 272

*General Index to subjects on page 371.

Digitized by Google

(Contents, Continued)

PAGE

MOUNTING BALL BEARINGS.
A. Riebe ..... 363
NEW TENSILE TEST PIECE AND HOLDER.
K. W. Zimmerschied ..... 161
OFFICERS OF THE SOCIETY ..... 369
PNEUMATIC TIRES.
P. W. Litchfield ..... 208
POWER VARIATION WITH ATMOSPHERIC CHANGE.
Herbert Chase ..... 185
PRESIDENTIAL ADDRESS ..... 57
REPORT OF TELLERS OF ELECTION OF MEMBERS ..... 58
SALES DEPARTMENT INFLUENCE ON DESIGN.
F. E. Moskovics ..... 236
SECTIONS OF THE SOCIETY ..... 370
STANDARDS COMMITTEE GENERAL REPORT ..... 70
MEETING ..... 1
STEAM OMNIBUSES.
Thomas Clarkson ..... 91
STORAGE BATTERY INSTRUCTIONS ..... 2, 69
TREASURER'S REPORT ..... 58, 304
TRUCK STANDARDS DIVISION REPORT ..... 1, 65
WIRE WHEELS.
George W. Houk ..... 223

Digitized by Google

# CONTRIBUTORS AND SPEAKERS


PAGE

H. W. ALDEN....281*
J. A. ANGLADA....355, 356, 358
B. B. BACHMAN....50
F. S. BENNETT....232, 244
C. T. F. BENSON....231
E. T. BIRDSALL....65, 68, 107, 135, 332, 333
L. S. BOWERS....67, 290
A. E. BRION....90
A. B. BROWNE....192*, 202, 205, 206
T. B. BROWNE....57, 58, 75*, 89, 90, 103, 134, 206, 207, 230
A. P. BRUSH....178, 181
W. L. BURGESS....55, 56
J. P. CARRITTE....324, 325, 326, 327
JOHN R. CAUTLEY....293
HERBERT CHASE....133, 183*, 186, 187, 188, 207, 332, 334, 335, 355, 359, 360, 362, 363
CHARLES A. CHEVRAUX....252
H. D. CHURCH....279*
C. F. CLARKSON....58, 359
THOMAS CLARKSON....89, 91*, 103, 104, 105, 106, 107, 231, 268, 269, 271, 292
H. E. COFFIN....71, 74
W. H. CONANT....69
H. L. CONNELL....318, 319
F. CONRAD....68
C. E. COX....166*, 178, 180, 181, 182, 319, 320*, 324, 327, 335
L. V. CRAM....180, 205
P. P. DEAN....346*, 354, 355, 356, 357, 358, 359, 360
GEORGE W. DUNHAM....245, 246
J. B. DUNLOP....216
W. E. FARRELL....286*, 291
T. J. FAY....68, 178
DAVID FERGUSSON....7, 64, 65, 67, 90
D. FITZPATRICK....106
E. S. FOLJAMBE....64, 165
E. R. FRIED....182
G. F. FULLER....48, 49, 50, 59, 146, 164
HARRY GOLDBERG....325, 326, 327
C. P. GRIMES....133, 187, 188*, 201, 202, 204, 206
H. D. HAIGHT....254


*Papers or Written Communications.

Digitized by Google

**(Contributors and Speakers, Continued)**


PAGE

J. E. Hale ..... 292
E. R. Hall ..... 55, 230
V. R. Heftler ..... 179
A. Holmes ..... 71*
H. L. Horning ..... 134
George W. Houk ..... 223, 231
W. S. Hovey ..... 313
Russell Huff ..... 145, 146, 147
F. G. Hughes ..... 65, 368
F. J. Jarosch ..... 368
F. Jehle ..... 134, 187, 191, 328*, 332, 333, 334, 335
Benj. Jerome ..... 283*
Phineas Jones ..... 286*
T. S. Kemble ..... 201
W. P. Kennedy ..... 1, 5, 50, 54, 55, 65, 90, 105, 360
V. W. Kliesrath ..... 314, 315, 316, 317, 318
R. W. Knowles ..... 355, 357, 358
E. F. Lake ..... 248*
W. C. Lamken ..... 135
A. M. Laycock ..... 263*, 271, 272, 287*
Henry M. Leland ..... 297*
P. W. Litchfield ..... 208*, 216, 222, 223
H. G. McComb ..... 359
W. R. McCulla ..... 319, 320, 334, 335
A. L. McMurtry ..... 356, 362
M. R. Machol ..... 354, 355, 358, 360, 362, 363
Howard Marmon ..... 6, 7, 56, 57, 58, 61, 63, 64, 65, 67, 68, 70, 71, 74, 89, 103, 107, 145, 160, 164, 165, 187, 216, 222, 228, 230, 231, 243, 268, 269
Prof. W. C. Marshall ..... 357, 360
A. F. Masury ..... 355, 356
J. Morat ..... 289*
R. L. Morgan ..... 285*
Prof. W. Morgan ..... 110*
Bert Morley ..... 285*
F. E. Moskovics ..... 146, 229, 230, 236*, 246, 247
C. S. Mott ..... 232
C. T. Myers ..... 269, 270, 314, 315, 319, 320, 321, 327
Bernard Nagelvoort ..... 135
F. P. Nehrbas ..... 247
R. J. Nightingale ..... 5
L. G. Nilson ..... 368
W. H. Palmer, Jr. ..... 5, 69
N. B. Pope ..... 89, 356, 357, 359
T. C. Pullinger ..... 106, 230, 244
A. Riebe ..... 363*, 368
E. F. Roberts ..... 136*
A. W. Robinson ..... 280*
A. J. Slade ..... 105, 222, 272*, 295


Digitized by Google

**(Contributors and Speakers, Continued)**

PAGE

HENRY SOUTHER.....5, 6, 47, 48, 50, 54, 55, 56, 59, 63, 64, 70, 100, 105, 146, 160, 164, 165, 234, 328
A. I. STEVENS..... 320
C. H. TAYLOR.....106, 180, 191, 222, 269, 271, 324, 327
P. S. TICE.....204, 306*, 316, 317, 318, 319, 320, 321, 333, 334, 335, 336*
HARRY TIPPER .....255*
ENRIQUE TOUCEDA .....148*
F. W. TRABOLD.....282*
F. H. TREGO.....331, 332, 333, 335
Q. TWACHTMAN ..... 358
J. G. VINCENT.....67, 68, 207, 228, 229, 244
J. H. WAGENHORST..... 56
W. G. WALL..... 233
E. W. WEAVER..... 145
CHARLES WHEELER.....74, 108*, 222, 223, 232
E. R. WHITNEY..... 56
C. B. WHITTELSEY.....50, 56, 295
JOHN WILKINSON ..... 133, 202
H. C. WILSON..... 230
E. B. WOOD.....110*, 134, 135, 177, 191, 201
PROF. K. W. ZIMMERSCHIED.....161*, 164

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# SEMI-ANNUAL MEETING OF THE SOCIETY OF AUTOMOBILE ENGINEERS

Held on
SS. City of Detroit III,
Detroit - Sault Ste. Marie, June 4-7, 1913

## MEETING OF THE STANDARDS COMMITTEE

The regular semi-annual meeting of the Standards Committee was held on board the *City of Detroit III*, on the evening of June 4, 1913. Mr. Henry Souther, Chairman of the Committee, presided. In addition to twenty-seven members of the committee, more than a dozen other members of the Society were present. Some of the visiting British automobile engineers also attended the meeting.

### TRUCK STANDARDS DIVISION REPORT

WILLIAM P. KENNEDY.—Mr. Chairman, while the Truck Standards Division has no formal report to offer, we are in a position to report progress. The work which it has in hand is of very large scope. We have made a great deal of research. We have determined to go slowly and surely. We have divided our committee into subcommittees, which we term equipment committees, to make research and recommendations to the committee as a whole, for the purpose of determination and action. The Wheel Equipment Committee will ascertain if possible whether we can consistently recommend practice which would reduce the number of wheel diameters now in use, or recommend practice which will confine the diameters to increments which will leave scope for increasing diameters in such a manner as to eliminate a number of the wheel diameters at present in use which seem to be unwarranted. The Power-plant Equipment Committee is endeavoring to determine whether we can recommend power plants for stated capacities of trucks without limiting in any way the designer in his province. The Spring and Axle Equipment Committee will recommend practice, as far as possible, in definite sizes of axles, springs, spring pads, etc. A fourth equipment committee will take into consideration what we call auxiliary apparatus, such as performance-recording devices, speed indicators, radiators, radiator at-

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tachments, body irons and minor parts of truck equipment which can be classified as auxiliary to the general truck.

CHAIRMAN SOUTHER.—If there is nothing further on that, the report of the Truck Standards Division to this Society will be one of progress only.

## FOURTH REPORT OF BALL AND ROLLER BEARINGS DIVISION

The fourth report of the Ball and Roller Bearings Division was submitted by Chairman David Fergusson, and approved for submission to the Society for acceptance. At the Society meeting held on the following day, however, consideration of the report was, pursuant to a request from representatives of ball bearings manufacturing companies, postponed until the Winter Meeting of the Society. (See page 64 of this volume.)

## INSTRUCTIONS FOR THE INSTALLATION AND CARE OF STORAGE BATTERIES USED IN CONNECTION WITH ELECTRIC STARTING AND LIGHTING SYSTEMS ON AUTOMOBILES

1. **Batteries must be properly installed.**

*Keep battery securely fastened in place.*

Battery must be accessible to facilitate regular adding of water to, and occasional testing of, solution. Battery compartment must be ventilated and drained, must keep out water, oil and dirt and must not afford opportunity for anything to be laid on top of battery. Battery should have free air space on all sides, should rest on cleats rather than on a solid bottom and holding devices should grip case or case handles. A cover, cleat or bar pressing down on the cells or terminals must not be used.

2. **Keep battery and interior of battery compartment wiped clean and dry.**

*Do not permit an open flame near the battery.*

Keep all small articles, especially of metal, out of and away from the battery. Keep terminals and connections coated with vaseline or grease. If solution has slopped or spilled, wipe off with waste wet with ammonia water.

3. **Pure water must be added to all cells regularly and at sufficiently frequent intervals to keep the solution at the proper height.**

*The proper height for the solution is usually given on the instruction- or name-plate on the battery. In all cases the solution must cover the battery plates.*

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The frequency with which water must be added depends largely upon the battery, the system with which it is used and the condition of operation. Once every two weeks is recommended as good practice in cool weather; once every week in hot weather.

*Plugs must be removed to add water: then replaced and screwed home after filling.*

*Do not use acid or electrolyte, only pure water.*

Do not use any water known to contain even small quantities of salts of any kind. Distilled water, melted artificial ice or fresh rain water are recommended.

Use only a clean non-metallic vessel.

Add water regularly, although the battery may seem to work all right without it.

**4. The best way to ascertain the condition of the battery is to test the specific gravity (density) of the solution in each cell with a hydrometer.**

*This should be done regularly.*

*A convenient time is when adding water, but the reading should be taken before, rather than after, adding the water.*

*A reliable specific gravity test cannot be made after adding water and before it has been mixed by charging the battery or by running the car.*

The cut illustrates a common and convenient form of hydrometer syringe to test the specific gravity of the electrolyte. To take a reading insert the end of the rubber tube in the cell. Squeeze and then slowly release the rubber bulb, drawing up electrolyte from the cell until the hydrometer floats. The reading on the graduated stem of the hydrometer at the point where it emerges from the solution is the specific gravity of the electrolyte. After testing, *the electrolyte must always be returned to the cell from which it was drawn.*

The gravity reading is expressed in "points"; thus the difference between 1,250 and 1,275 is 25 points.

**5. When all cells are in good order the gravity will test about the same (within 25 points) in all.**

*Gravity above* 1,200 *indicates battery more than half charged.*

*Gravity below* 1,200 *but above* 1,150 *indicates battery less than half charged.*

When battery is found to be half discharged use lamps sparingly until by charging the battery the gravity is restored to at least 1,200. See Section 8.

*Gravity below* 1,150 *indicates battery completely discharged or "run down."*

A run-down battery should be given a full charge at once. See Sections 7 and 8.

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A run-down battery is always the result of lack of charge or waste of current. If, after having been fully charged the battery soon runs down again there is trouble somewhere else in the system, which should be located and corrected.

Putting acid or electrolyte into the cells to bring up specific gravity can do no good and may do great harm. Acid or electrolyte should never be put into the battery except by an experienced battery man.

**6. Gravity in one cell markedly lower than in the others especially if successive readings show the difference to be increasing, indicates that the cell is not in good order.**

*If the cell also regularly requires more water than the others, a leaky jar is indicated.*

Even a slow leak will rob a cell of all its electrolyte in time, and a leaky jar should be immediately replaced with a good one.

*If there is no leak and if the gravity is, or becomes, 50 to 75 points below that in the other cells, a partial short-circuit or other trouble within the cell, is indicated.*

A partial short-circuit may if neglected seriously injure the battery and should receive the prompt attention of a good battery repair man.

**7. A battery charge is complete when, with charging current flowing at the rate given on the instruction-plate on the battery, all cells are gassing (bubbling) freely and evenly and the gravity of all cells has shown no further rise during one hour.**

*The gravity of the solution in cells fully charged as above is 1,275 to 1,300.*

**8. The best results in both starting and in lighting service will be obtained when the system is so designed and adjusted that the battery is normally kept well charged, but without excessive overcharging.**

*If, for any reason, an extra charge to maximum specific gravity is needed, it may be accomplished by running the engine idle, or by using direct current from an outside source.*

In charging from an outside source use *direct* current only. Limit the current to the proper rate in amperes by connecting a suitable resistance in series with the battery. Incandescent lamps are convenient for this purpose.

Connect the positive battery terminal (painted red, or marked POS or P or +) to the positive charging wire and negative to negative. If reversed, serious injury may result. Test charging wires for positive and negative with a voltmeter or by dipping the ends in a glass of water containing a few drops of electrolyte, when bubbles will form on the negative wire.

**9. A battery which is to stand idle should first be fully charged. See Sections 7 and 8.**

*A battery not in active service may be kept in condition for use by giving it a freshening charge at least once every two months, but should preferably also be given a thorough charge, after an idle period, before it is replaced in service.*

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*A battery which has stood idle for more than two months should be charged at one-half normal rate to maximum gravity before being replaced in service.*

*It is not wise to permit a battery to stand for more than six months without charging.*

Disconnect the leads from a battery that is not in service so that it may not lose through any slight leak in car wiring.

## DISCUSSION

WM. H. PALMER, JR.—With regard to the preparation of some form of standard battery instruction, all the battery manufacturers who were making batteries used in connection with starting and lighting equipment were trying to say about the same thing, but they were saying it in rather different ways. The result was that some confusion existed, making it somewhat difficult for the automobile manufacturers in the preparation of their instruction books to incorporate battery instructions which would be applicable to a variety of makes of batteries. A subcommittee of the Electrical Equipment Division prepared a set of standard instructions. The subcommittee communicated with and ascertained the feeling of those of the battery manufacturers with whom they could get in touch. The situation seems to be that the manufacturers agree that instructions should be prepared to serve in general as a good guide for the care and the installation of batteries, but that in every case the battery manufacturer has some peculiarities of construction which make it necessary for him to amplify or change those instructions in slight particulars in order to make them apply fully to his product. But the feeling is very strong that a form of general instructions which can be adopted by all manufacturers is a very good thing. The instructions presented here are indorsed to that extent and approved by the following manufacturers: The Electric Storage Battery Company, Gould Storage Battery Company, United States Light & Heating Company, Willard Storage Battery Company and the Philadelphia Storage Battery Company. The instructions as prepared are therefore submitted for acceptance as recommended practice.

CHAIRMAN SOUTHER.—This is another one of the reports, gentlemen, that is bound to take the form of instructions rather than standards. If the designer persists in putting the battery on top of his car or somewhere else, I do not see that we can stop him. But if he is in doubt as to where it should go and will refer to this printed matter he will get a pretty fair idea of what is good practice. This can be presented to the Society as engineering information, with the Standards Committee as the origin. Are there any other remarks on this report?

WILLIAM P. KENNEDY.—Do the instructions cover lead batteries only?

WILLIAM H. PALMER, JR.—The thought was that for the present, at least, the Edison battery is not used in connection with starting systems.

R. J. NIGHTINGALE.—We are building a considerable number of batteries for starting and lighting. I feel that the ordinary user is entirely at sea as to the care and attention necessary for continued success with

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the system. If the starting and lighting machine manufacturers could get together on common ground and recommend that these instructions be inserted in the car manufacturers' instruction book, together with the instructions on other accessories, we could accomplish good to the individual car and machine manufacturer and lastly to the battery manufacturer. We find that all the battery manufacturers agree on a certain compromise as to what the battery instructions must be. If these are read in open meeting and afterwards go to the various manufacturers, thus early in the lighting and starting business, I believe it will keep us away from a lot of grief later on.

CHAIRMAN SOUTHER.—That is a clear statement of the benefit of such a report.

(President Marmon takes the chair.)

## PNEUMATIC RIM STANDARDIZATION

CHAIRMAN PRO TEM MARMON.—Mr. Souther, the chairman of the Pleasure Car Wheels Division will make a report.

HENRY SOUTHER.—The members of the committee present will recall that last winter a committee was formed to take up the question of reducing the number of rims for pleasure car wheels, if possible, and also to take up the question of the wire wheel standard wherever possible. Work was begun at once and is proceeding. The committee has recommended the acceptance of the standard clincher rim dimensions of the Clincher Automobile Tire Manufacturers Association for one-piece clincher rim dimensions.

As I see it, it is clear that there will have to be three types of Q. D. rims: a universal, which will permit of the reversal of the rings and the use of the rim for either a straight-side or a clincher tire. It is made clear by the tire manufacturers that there are so many universal rims in the market that to attempt to eliminate them at once would be a mistake. It is also evident that the straight-side tire is gaining in favor and that a straight-side Q. D. rim must be accepted. It is also clear that the hook side Q. D., with one loose ring or two loose rings, will have to be accepted.

No conclusion has been reached, for a very simple reason, and one of very great importance as it seems to your committee. The strength of Q. D. rims immediately came to the front. When I say strength I mean how much internal pressure in the tire it takes to destroy a Q. D. rim one way or another. Mr. David Fergusson has been one of the critics of the strength of the rim and brings out the fact that some rims are much weaker than others. At any rate, in view of the fact that there is a strong tendency towards lightening rims and wheel parts in general, your committee must proceed with a good deal of care in the recommendation of any type of rim. The Goodyear Rubber Company and the United States Rubber Company have both come forward and offered to test such rims as will be placed in their hands for testing. The character of the test is to be air pressure; that is to say, the tube and shoe will be placed upon the rim and air pressure applied until something

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yields. Until we know the comparative strength of the various rims on the market and of the various proposed rims, we will hardly be in a position to make any recommendations at all.

In the matter of demountable rims we have had brought before us no end of designs and modifications. Although we have taken no vote as a committee, I feel like saying that the matter must remain in abeyance for another meeting or two, with the continual attempt being made to get at something. Just one concrete suggestion has been made that I hope our demountable rim people will seize upon for their own benefit, and that is that the tightening nuts shall not be of different size or shape. There must be at least two about alike, and if you can get three so much the better.

DAVID FERGUSSON.—Should we not recommend some pressure that the rims ought to at least stand?

CHAIRMAN SOUTHER.—Mr. Fergusson, I do not believe we know what that is. We do know that three or four rims are standing up perfectly well in common use; that the number of failures is as small as humanly possible with the best of machinery. Those have been tested more or less, not officially, but unofficially, and it would seem that 230 to 250 pounds per square inch is the figure of a successful rim of today. I am not saying that is right. But plenty of successful rims fail at 250 pounds, if I may say so. Now just why that is we are not prepared to say. My own thought in the matter is that 300 pounds is a good big margin of safety.

CHAIRMAN MARMON.—Are there any further comments? If not we will accept the report as one of progress and submit it to the general meeting as such.

# Fourth Report
of
# IRON AND STEEL DIVISION
## Revised Notes and Instructions Referring to Materials Specified*

*For Specifications see S. A. E. Transactions, Vol. 7, Part I, p. 33 (Third Report of Iron & Steel Division, accepted January, 1912), and S. A. E. Data Sheets Vol. I, 9-9c.

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## REGARDING NOTES AND INSTRUCTIONS

**The notes and instructions on the chemical specifications are not to be considered in any way a part of these Specifications. They are added solely for the information of the user of the steels and for the guidance of the purchaser in the selection of proper steels for his different purposes. They should not be incorporated in the specification when ordering steel. This is especially true of the "Physical Characteristics."**

The materials specified in detail in the third report of the Iron and Steel Division, include the most important ones available to the builder of automobiles. It is obvious that there are more kinds of material specified than are likely to be used by any one manufacturer.

The results of physical tests, whether tension tests or otherwise, are largely dependent upon the mass and form of the specimen tested. This is particularly true of heat treated steels. For the foregoing reason, all results of physical tests are comparative, and in order to make the comparison a proper one a uniform test specimen must be used.

The Committee therefore decided that recommended practice should be the use of the S. A. E. standard test specimen, this specimen to be treated always in its finished form and not in the rough shape from which the finished specimen might be cut.

The figures for physical characteristics refer to those obtained on specimens prepared from sections common in automobile use, that is, bars from 1 inch round up to 1½ inches round. The high yield points may be obtained with severe heat treatments, and the lower yield points with treatments less severe.

The yield point is specified rather than the elastic limit. The yield point is measured by the drop of the testing machine beam and may safely be relied upon for material having a yield point not in excess of 100,000 lbs. per square inch. With material having a yield point in excess of 100,000 lbs. per square inch the true elastic limit should be obtained by means of an extensometer.

In addition to the usual physical characteristics the "hardness" tests have been considered, as obtained by means of the Brinell ball test and the Shore scleroscope. The Brinell test recommended by the committee is the use of the 10 millimeter ball and 3,000 kilogram load. It is pointed out, however, that the Brinell test must not be used on soft steels less than ½ inch thick, or on areas small enough to permit the depression to flow toward the edges of the specimen. With hard steels, where the depth of the depression and the flow of metal are less, material as thin as ¼ inch may be so tested. The Brinell test may be fairly made on surfaces that are free from scale and smooth.

The Shore test (scleroscope) must be used only on surfaces that have been carefully polished and free from all tool marks, file marks or grinding scratches.

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# CARBON STEELS

## *SPECIFICATION No.* 10—10

### .10 *Carbon Steel*

This is usually known in the trade as soft, basic open hearth steel. It is a material commonly used for the seamless tubing, pressed steel frames, pressed steel brake-drums, sheet steel brakebands and pressed steel parts of many varieties. It is soft and ductile and will stand much deformation without cracking.

This steel in a natural or annealed condition is of low strength, and must not be used where much strength is required. This quality of material is considerably stronger after cold drawing or rolling; that is, its yield point is raised by such working. This is important in view of the fact that many wire and sheet metal parts above mentioned are used in the cold rolled or cold drawn form.

It must not be forgotten that when this steel (so cold worked) is heated, as for bending, brazing, welding, or the like, the yield point returns to that characteristic of the annealed material. *This remark also applies to all materials that have an increased yield point produced by cold working.*

This material in a natural or annealed state does not machine freely. It will tear badly in the turning, threading and broaching operations. Heat treatment produces but little benefit, and that not in strength but in toughness. It is possible to quench this grade of steel and put it in a condition to machine better than the annealed state.

The heat treatment which will produce a little stiffness is to quench at 1500° F. in oil or water. No drawing is required.

This steel will case-harden but is not as suitable for this purpose as Steel 10—20, a note on which follows.

*Physical Characteristics*

| | Annealed | Cold Rolled or Cold Drawn |
|---|---|---|
| Yield point, lbs., per sq. in | 28,000 to 36,000 | 40,000 to 60,000† |
| Reduction of area | 65-55% | 55-45% |
| Elongation in 2" | 40-30% | Unimportant |

## *SPECIFICATION No.* 10—20

### .20 *Carbon Steel*

This steel is known to the trade as .20 carbon, open hearth steel, and often as machine steel.

†These high yield points can be obtained only in comparatively light or small sections, either in the sheet or rod form; say one-half inch round or one-quarter inch sheets or flats.

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This quality is intended primarily for case-hardening. It forges well and machines well, but should not be considered as screw machine stock. It may therefore be used for a very large variety of forged, machined and case-hardened parts of an automobile where strength is not paramount.

Steel of this quality may also be drawn into tubes and rolled into cold rolled forms, and, as a matter of fact, makes a better frame than Steel 10—10, because of the slightly higher carbon and resulting strength. The increased carbon content has no detrimental effect as far as usage is concerned, and it is only the most difficult of cold forming operations that cause it to crack during the forming. For automobile parts it may be safely used interchangeably with Steel 10—10 as far as cold pressed shapes are concerned.

Heat treatment of this steel produces but little change as far as strength is concerned, but does cause a desirable refinement of grain after forging, and the toughness is materially increased. A simple quenching operation from about 1500° F. in oil, is all that is necessary. Treatment will often help the machining qualities.

Case-hardening is the most important treatment for this quality of steel. The character of the operation must depend upon the importance of the part to be treated and upon the shape and size. There is a certain group of parts in an automobile which are not called upon to carry much load or withstand any shock. The principal requirement is hardness. Such parts are fairly illustrated by screws and by rod-end pins. The simplest form of case-hardening will suffice, viz.:

*Heat Treatment A*

After forging or machining—

1. Carbonize at a temperature between 1600° F. and 1750° F. (1650°-1700° F. desired).
2. Cool slowly or quench.
3. Reheat to 1500-1550° F. and quench.

Another class of parts demands the best treatment (Heat Treatment B), such as gears, steering-wheel pivot-pins, cam-rollers, push-rods and many similar details of an automobile which the manufacturer learns by experience must be not only hard on the exterior surface but must possess strength as well. The desired treatment is one which first refines and strengthens the interior and uncarbonized metal. This is then followed by a treatment which refines the exterior, carbonized, or high carbon metal.

*Heat Treatment B*

After forging or machining—

1. Carbonize at a temperature between 1600° F. and 1750° F. (1650°-1700° F. desired).
2. Cool slowly in the carbonizing mixture.
3. Reheat to 1500°-1550° F.
4. Quench.

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5. Reheat to 1400°-1450° F.
6. Quench.
7. Draw in hot oil at a temperature which may vary from 300° F. to 450° F., depending upon the degree of hardness desired.

In the case of very important parts, the last drawing operation should be continued from one to three hours, to insure the full benefit of the operation.

The objects of drawing are two-fold: First, and not least important, is the relieving of all internal strains produced by quenching; second is the decrease in hardness, which is sometimes desirable. The hardness begins to decrease very materially from 350° F. up, and the operation must be controlled as dictated by experience with any given part.

There are certain very important pieces that demand all of these operations, but the last drawing operation may be omitted with a large number. Experience teaches what degree of hardness and toughness combined is necessary for any given part. It is impossible to lay down a general rule covering all different uses. If the fundamental principle is well understood, there should be no trouble in developing the treatment to a proper degree.

Following the foregoing treatment, a fractured part should show a fine-grained exterior, without any appearance of shiny crystals. The smaller the crystals the better. The interior may show a silky, fibrous condition or a fine crystalline condition; but it must not show a coarse, shiny, crystalline condition.

*Physical Characteristics*

| | Annealed | Cold Rolled or Cold Drawn | Heat Treatment C or D |
|---|---|---|---|
| Yield point, lbs., per sq. in..... | 30,000 to 40,000 | 40,000 to 75,000† | 40,000* to 75,000 |
| Reduction of area..... | 60-45% | 35-30% | 60-30% |
| Elongation in 2"..... | 35-25% | Unimportant | 35-15% |

There is little use in giving the physical characteristics of a carbonized steel, inasmuch as any test must be deceptive because of the very high carbon exterior case which cracks and fails long before the soft and tough

---

★**NOTE.—The yield point is under control in two ways—by choice of quenching medium (oil, water or brine) and by varying the final drawing temperature. In the interpretation of the physical characteristic figures, it must be remembered that only the minimum figures as to toughness (i.e., reduction and elongation) may be expected with the highest degree of strength (i.e., yield point); and, conversely, that the highest degree of toughness may be expected with the lowest yield point.** ***This remark applies to all heat treated steels.*** **It would be manifestly impossible to obtain the highest percentage of elongation and the highest yield point on the same specimen.**

† In sections not over one-half inch round or one-quarter inch sheets or flats.

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interior does. This means that the rupture is fragmental and progressive, and misleading.

## *SPECIFICATION No. 10—30.*

### *.30 Carbon Steel.*

This material is sometimes referred to in the trade as .30 carbon machine steel.

It is primarily for use as a structural steel. It forges well, machines well and responds to heat treatment in the matter of strength as well as toughness; that is to say, intelligent heat treatment will produce marked increase in the yield point. It may be used for all forgings such as axles, driving-shafts, steering pivots and other structural parts. It is the best all-round structural steel for such use as its strength warrants.

Heat treatment for toughening and strength is of importance with this steel. The heat treatment must be modified in accordance with the experience of the individual user, to suit the size of the part treated and the combination of strength and toughness desired. The steel should be heat treated in all cases where reliability is important.

Machining may precede the following heat treatment, depending somewhat upon convenience and the character of the treatment. If the highest strength is demanded, a strong quenching medium must be employed; for example, brine. In such case, the yield point will be correspondingly high and the steel corresponding hard and difficult to machine. On the other hand, if a moderately high yield point is all that is desired, an oil quench will suffice and machining may follow without any difficulty whatever.

#### *Heat Treatment C.*

After forging or machining—

1. Heat to 1475°-1525° F.
2. Quench.
3. Reheat to 600°-1200° F. and cool slowly.

This is the simplest form of heat treatment. The drawing operation (No. 3) must be varied to suit each individual case. If great toughness and little increased strength are desired, the higher drawing temperatures may be used, that is in the neighborhood of 1100° F. to 1200° F. If much strength is desired and little toughness, the lower temperatures are available. Even the lowest of the temperatures given will produce a quality of steel, after oil quenching, that is very tough—sufficiently tough for many important parts. In fact, with some parts the drawing operation (No. 3) may be entirely omitted.

Results better than obtainable with the above sequence of operations may be obtained by a double treatment, viz:

#### *Heat Treatment D*

After forging or machining—

1. Heat to 1500°-1550° F.

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2. Quench.
3. Reheat to 1450°-1500° F.
4. Quench.
5. Reheat to 600°-1200° F. and cool slowly.

This produces a refinement of grain not possible with one treatment and is resorted to in parts where extremely good qualities are desired.

This quality of steel is not intended for case-hardening, but by careful treatment it may be safely case-hardened. This should be in emergencies only, rather than as a regular practice and, if at all, only with the double treatment followed by the drawing operation; that is, the most painstaking form of case-hardening.

*Physical Characteristics*

| | Annealed | Cold Rolled or Cold Drawn | Heat Treatment C or D |
|---|---|---|---|
| Yield point, lbs., per sq. in | 35,000 to 45,000 | Not usually worked in this manner, except for wire. | 40,000 to 80,000 |
| Reduction of area | 55-40% | | 60-30% |
| Elongation in 2" | 30-20% | | 30-10% |

## *SPECIFICATION No.* 10—40

### .40 *Carbon Steel*

This material is ordinarily known to the trade as .40 carbon machine steel.

This quality represents a structural steel of greater strength than Steel 10—30. Its uses are more limited and are confined in a general way to such parts as demand a high degree of strength and a considerable degree of toughness. At the same time, with proper heat treatment the fatigue-resisting (endurance) qualities are very high—higher than with any of the foregoing specifications.

This steel is commonly used for crankshafts, driving-shafts and propeller-shafts. It has also been used for transmission gears, but it is not quite hard enough without case-hardening and is not tough enough with case-hardening to make safe transmission gears. It should not be used for case-hardened parts. Other steels are decidedly better for this purpose.

In a properly annealed condition it machines well,—not well enough for screw machine work; but certainly well enough for all-round machine shop practice.

A good heat treatment for this quality of steel for crankshafts and similar parts is as follows:

*Heat Treatment E*

After forging or machining—

1. Heat to 1500°-1550° F.

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2. Cool slowly.
3. Reheat to 1450°-1500° F.
4. Quench.
5. Reheat to 600°-1200° F. and cool slowly.

*Physical Characteristics*

| | Annealed | Heat Treatment E |
|---|---|---|
| Yield point, lbs. per sq. in | 40,000 to 50,000 | 45,000 to 100,000 |
| Reduction of area | 50-40% | 55-25% |
| Elongation in 2" | 25-20% | 25- 5% |

*SPECIFICATION No.* 10—50

.50 *Carbon Steel*

This steel differs very little from Steel 10—40. Owing to its higher carbon content it is somewhat harder to machine, but not seriously. It is also somewhat stronger. It can be used for gears with a little better results than the preceding steel. The same form of heat treatments (excluding case-hardening) may be used, with suitable modifications to fit individual cases.

*Physical Characteristics*

| | Annealed | Heat Treatment E |
|---|---|---|
| Yield point, lbs. per sq. in | 45,000 to 60,000 | 50,000 to 110,000 |
| Reduction of area | 40-30% | 50-15% |
| Elongation in 2" | 20-15% | 20- 5% |

*SPECIFICATION No.* 10—80

.80 *Carbon Steel*

This quality is ordinarily known to the trade as spring steel. Its use generally is for springs of light section.

The hardening and drawing of springs, that is, the heat treatment of them, is, as a rule, in the hands of the springmaker, but in case it is desired to treat, as for small springs, the following is recommended:

*Heat Treatment F*

After shaping or coiling—

1. Heat to 1450°-1500° F.
2. Quench in oil.
3. Reheat to 400°-800° F., in accordance with degree of temper desired, and cool slowly.

It must be understood that the higher the drawing temperature (Operation 3), the lower will be the yield point of the material. On the other hand, if the material be drawn at too low a temperature, it will be brittle. A few practical trials will locate the best temper for any given shape or size.

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*Physical Characteristics*

The physical characteristics of heat treated spring steel are best determined by transverse test. This is because steel as hard as tempered spring steel is very difficult to hold firmly in the jaws of a tensile testing machine. There is more or less slip, and side strains are bound to occur, all of which tends to produce misleading results.

The physical characteristics in the annealed condition may be omitted, inasmuch as this grade of steel is not ordinarily used for structural parts in such condition.

Careful examination of the fracture of the treated material is desirable. After tempering no suitable spring steel should be coarsely crystalline. It should be finely crystalline, and in some cases should show a partly fibrous fracture.

*Physical Characteristics*
(Transverse Test.)

| | Heat Treatment F |
|---|---|
| Elastic limit (initial set), lbs. per sq. in..... | 90,000 to 160,000 |
| Reduction of area..... | Not determined in transverse test |
| Elongation ..... | do |

*SPECIFICATION No.* 10—95

*.95 Carbon Steel*

This is a grade of steel used generally for springs. Properly heat treated, extremely good results are possible. Substantially the same remarks apply to this quality of steel as to Steel 10—80. It is possible that the quenching temperature (Operation 1, Heat Treatment F) may be lowered slightly because of the increase in carbon, and it is also probable that the drawing temperature (Operation 3) will not be the same.

*Physical Characteristics*

The physical characteristics of a tempered spring of this quality are substantially those of Steel 10—80, possibly a little higher. The thought will naturally arise as to what is to be gained by the use of this material. The answer is that this steel will possess a finer grain and endure longer, providing the treatment is suitable; also, that with thicker and heavier metal the treatment will penetrate deeper because of the increased carbon content. It is for this reason that this quality of steel should be used for the heavier types of springs.

The same remarks as made in regard to tests and inspection in connection with Steel 10—80 apply to this steel.

## SCREW STOCK

*SPECIFICATION No.* 11—14

This steel may be made by any process. It is intended for use where high screw machine production is the important factor, strength and

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toughness being a secondary consideration. Its composition and texture are of such nature as to permit the rapid removal of metal and a resulting smoothness of finish.

## STEEL CASTINGS

*SPECIFICATION No. 12—35*

*Steel Castings*

Steel castings may be made by any approved process.

Genuine steel castings, and not malleable iron or complex mixtures often found in the market masquerading under the name of steel, are referred to.

Genuine steel castings should be annealed and may be heat treated to great advantage. A steel casting of the composition given in the specification should be so tough as to bend to a considerable angle before breaking. The yield point of such a casting in an annealed condition is in the neighborhood of 35,000 lbs. per square inch.

Like other castings, steel castings are subject to blow-holes. Consequently, they should not be used in the vital parts of an automobile. It is impossible to inspect against blow-holes, and steel castings for axles, crankshafts and steering spindles are used only at great risk. The specification has been prepared with the idea of furnishing a fair commercial analysis. Freedom from blow-holes and proper physical condition are of more importance than the absolute analysis.

### REMARKS ON THE USE OF ALLOY STEELS

In connection with the purchase and use of alloy steels it should be borne in mind that such steels should be used in the treated condition only, that is, not in an annealed or natural condition. In the latter condition there is a slight benefit, perhaps, as compared with plain carbon steels, but as a rule nothing commensurate with the increased cost. In the heat treated condition, however, there is a very marked improvement in physical characteristics.

## NICKEL STEELS

*SPECIFICATION No. 23—15*

*.15 Carbon, 3½% Nickel Steel*

This quality of steel is embraced in these specifications to furnish a nickel steel that is suitable for carbonizing purposes. Steel of this character, properly carbonized and heat treated, will produce a part with an exceedingly tough and strong core, coupled with the desired high carbon exterior.

This steel is also available for structural purposes, but is not one to be selected for such purpose when ordering materials. Much better results will be obtained with one of the other nickel steels of higher carbon.

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It is intended for case-hardened gears, for both the bevel driving and transmission systems, and for such other case-hardened parts as demand a very tough, strong steel with a hardened exterior.

The case-hardening sequence may be varied considerably, as with Steel 10—20, those parts of relatively small importance requiring a simpler form of treatment. As a rule, however, those parts which require the use of nickel steel require the best type of case-hardening, viz:

*Heat Treatment G*

After forging or machining—

1. Carbonize at a temperature between 1600° F. and 1750° F. (1650°-1700° F. desired).
2. Cool slowly in the carbonizing material.
3. Reheat to 1500°-1550° F.
4. Quench.
5. Reheat to 1300°-1400° F.
6. Quench.
7. Reheat to a temperature from 250°-500° F. (in accordance with the necessities of the case) and cool slowly.

The second quench (Operation 6) must be conducted at the lowest possible temperature at which the material will harden. It will be found that sometimes this is lower than 1300° F.

In connection with certain uses it will be found possible to omit the final drawing (Operation 7) entirely, but for parts of the highest importance this operation should be followed as a safeguard. Parts of intricate shape, with sudden changes of thickness, sharp corners and the like, particularly sliding gears, should always be drawn, in order to relieve the internal strains.

*Physical Characteristics*

Much is to be learned from the character of the fracture. The center should be fibrous in appearance, and the exterior, high carbon metal closely crystalline, or even silky.

When used for structural purposes, the physical characteristics will range about at follows:

| | Annealed | Heat Treatment H or K |
|---|---|---|
| Yield point, lbs. per sq. in..... | 35,000 to 45,000 | 40,000 to 80,000 |
| Reduction of area..... | 65-45% | 65-40% |
| Elongation in 2"..... | 35-25% | 35-15% |

*SPECIFICATION No. 23—20*

*.20 Carbon, 3½% Nickel Steel*

This quality may be used interchangeably with Steel 23—15. Although intended primarily for case-hardening, it may be properly used for structural parts, with suitable heat treatment, and will give elastic

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limits somewhat higher than material provided by the preceding specification.

For case-hardening, Heat Treatment G should be followed, and for structural purposes the treatment should be in accordance with Heat Treatment H or K; the quenching temperatures, as with other steels, being modified to meet individual cases.

*Physical Characteristics*

| | Annealed | Heat Treatment H or K |
|---|---|---|
| Yield point, lbs. per sq. in | 40,000 to 50,000 | 50,000 to 125,000 |
| Reduction of area | 65-40% | 65-40% |
| Elongation in 2" | 30-20% | 25-10% |

## *SPECIFICATION No. 23—25*

### .25 *Carbon, 3½% Nickel Steel*

This is a quality of steel that may be case-hardened successfully. Suitable treatment (G) gives a product that is satisfactory for gears, whether of the transmission or rear axle bevel type. The treatment after carbonizing must be slightly modified to meet the increase in carbon content.

This is also a useful quality of steel for many structural parts, its response to heat treatment (either H or K) being most satisfactory.

*Physical Characteristics*

The physical characteristics of this steel may be considered as practically those obtained with Steel 23—20, slight modifications in the treatment much more than offsetting the slight difference in the carbon content.

| | Annealed | Heat Treatment H or K |
|---|---|---|
| Yield point or elastic limit, lbs. per sq. in | 40,000 to 50,000 | 60,000 to 130,000 |
| Reduction of area | 60-40% | 60-30% |
| Elongation in 2" | 30-20% | 25-10% |

## *SPECIFICATION No. 23—30*

### .30 *Carbon, 3½% Nickel Steel*

This quality of steel is primarily for heat treated structural parts where strength and toughness are sought; such parts as axles, front-wheel spindles, crankshafts, driving-shafts and transmission shafts. Wide variations of yield point or elastic limit are possible by the use of

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different quenching mediums—oil, water or brine—and variation in drawing temperatures, from 500° F. up to 1200° F.

The form of treatment is—

*Heat Treatment H*

After forging or machining—

1. Heat to 1500°-1550° F.
2. Quench.
3. Reheat to 600°-1200° F. and cool slowly.

A higher refinement of this treatment is:

*Heat Treatment K*

After forging or machining—

1. Heat to 1500°-1550° F.
2. Quench.
3. Reheat to 1300°-1400° F.
4. Quench.
5. Reheat to 600°-1200° F. and cool slowly.

This material may be case-hardened, but is rather high in carbon for the practice of the average case-hardening department. The lower ranges of carbon—in the neighborhood of .25—are satisfactory, but the upper ranges—in the neighborhood of .35—approach the danger point, and steel of the latter carbon content must be correspondingly carefully handled.

*Physical Characteristics*

| | Annealed | Heat Treatment H or K |
|---|---|---|
| Yield point or elastic limit, lbs. per sq. in..... | 45,000 to 55,000 | 65,000 to 150,000 |
| Reduction of area..... | 55-35% | 55-25% |
| Elongation in 2"..... | 25-15% | 25-10% |

*SPECIFICATION No. 23—35*

*.35 Carbon, 3½% Nickel Steel*

This quality of steel is subject to precisely the same remarks as Steel 23—30. It will respond a little more sharply to heat treatment and can be forced to higher elastic limits. The difference will be small except in extreme cases. It should not be used for case-hardening.

*Physical Characteristics*

| | Annealed | Heat Treatment H or K |
|---|---|---|
| Yield point or elastic limit, lbs. per sq. in..... | 45,000 to 55,000 | 65,000 to 160,000 |
| Reduction of area..... | 55-35% | 55-25% |
| Elongation in 2"..... | 25-15% | 25-10% |

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*SPECIFICATIONS Nos.* 23—40, 23—45 and 23—50

*.40 Carbon 3½% Nickel Steel*
*.45 Carbon, 3½% Nickel Steel*
*.50 Carbon, 3½% Nickel Steel*

The above nickel steels are qualities not in wide use but available for certain purposes.

The carbon contents being higher than generally used, greater hardness is obtainable by quenching; and as increased brittleness accompanies the greater hardness, the treatments given must be modified to meet such condition. For example, the final quench may be at a considerably lower temperature, and the final drawing temperature, or partial annealing, must be carefully chosen, in order to produce the desired toughness and other physical characteristics.

The strength of these steels, as with Steels 23—25, 23—30 and 23—35, depends upon the treatment and may be controlled closely over a wide range. The degree of brittleness must be carefully watched and controlled. Proper treatment will yield very strong and tough steel; not as tough as Steel 23—25, 23—30 and 23—35, but nevertheless tough enough to fill a number of needs.

*Physical Characteristics*

| | Annealed | Heat Treatment H or K |
|---|---|---|
| Yield point or elastic limit, lbs. per sq. in..... | 55,000 to 70,000 | 70,000 to 200,000 |
| Reduction of area..... | 50-30% | 55-15% |
| Elongation in 2"..... | 25-15% | 20- 5% |

## NICKEL CHROMIUM STEELS

These classes of alloy steel are important. There are three types in common use, the differences between them consisting in the amount of alloying elements present. The types may be classified as low nickel-medium nickel- and high nickel-chromium steels, viz., classes 31—, 32— and 33—, as given in the specifications.

In general it may be said that the heat treatments and the properties induced thereby are much the same as in the case of plain nickel steels, except that the effects of the heat treatments are somewhat augmented by the presence of the chromium, and further that these effects increase in these three types with increasing amounts of nickel and chromium.

### LOW NICKEL CHROMIUM STEELS

*SPECIFICATIONS Nos.* 31—15 *to* 31—50

*Low Nickel Chromium Steels*

Substantially the same remarks apply to these various types as apply to nickel steels. In other words, the carbon content may be varied from

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the lowest to the highest, depending upon the physical qualities sought. The physical characteristics obtainable will vary with the carbon, and the heat treatment must be chosen accordingly.

*Steels* 31—15 and 31—20 (.15 and .20 carbon) are intended primarily for case-hardening (Heat Treatment G). These steels ought not to be used in the natural condition, but if desired may be used for structural purposes, in which case Heat Treatments H and K are recommended.

*Steels* 31—25, 31—30, 31—35, 31—40 (.25 to .40 carbon) are intended primarily for structural purposes in a heat treated condition (Heat Treatments H and K). Steel 31—25 may be used for case-hardening, as also may Steel 31—30 if necessary.

*Steels* 31—45, 31—50 (.45 and .50 carbon) may be used for gears and other structural parts where a high degree of strength and hardness are demanded and where toughness is not of first importance. Heat Treatment K is recommended for such parts, the final drawing (Operation 5) being carried out at 250°-550° F., or at such temperature as will give the desired physical characteristics.

*Physical Characteristics*

| *Steels* 31—25, 31—30: | Annealed | Heat Treatment H or K |
|---|---|---|
| Yield point or elastic limit, lbs. per sq. in.. | 30,000 to 40,000 | 40,000 to 100,000 |
| Reduction of area | 55-40% | 65-40% |
| Elongation in 2" | 35-25% | 25-15% |

| *Steels* 31—25, 31—30: | Annealed | Heat Treatment H or K |
|---|---|---|
| Yield point or elastic limit, lbs. per sq. in. | 40,000 to 55,000 | 50,000 to 125,000 |
| Reduction of area | 50-35% | 55-25% |
| Elongation in 2" | 30-20% | 25-10% |

| *Steels* 31—35, 31—40: | Annealed | Heat Treatment H or K |
|---|---|---|
| Yield point or elastic limit, lbs. per sq. in. | 45,000 to 60,000 | 55,000 to 150,000 |
| Reduction of area | 50-30% | 50-25% |
| Elongation in 2" | 25-15% | 20- 5% |

| *Steels* 31—45, 31—50: | Annealed | Heat Treatment H or K |
|---|---|---|
| Yield point or elastic limit, lbs. per sq. in. | 55,000 to 70,000 | 60,000 to 175,000 |
| Reduction of area | 45-30% | 45-20% |
| Elongation in 2" | 25-15% | 15- 5% |

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## MEDIUM NICKEL CHROMIUM STEELS

*SPECIFICATIONS Nos. 32—15 to 32—50*

*Medium Nickel Chromium Steels*

It will be noted that this type of nickel chromium steel is of the same composition as the preceding type, except that it contains more nickel and more chromium. The physical characteristics are omitted for the reason that results will be obtained that are intermediate between the low nickel chromium alloys and the high nickel chromium alloys.

## HIGH NICKEL CHROMIUM STEELS

These steels differ from the two preceding types (31— and 32—) in the fact that they contain still more nickel and chromium.

Attention is called to the fact that there will be some difference noted between the high nickel chromium and the medium nickel chromium heat treatments. It will be found that the possible ranges of treatment will differ slightly; also that the resulting physical characteristics will vary correspondingly.

Annealing before machining will be found necessary for all carbons. The higher percentages of alloy elements make machining in a natural condition difficult.

*SPECIFICATION 33—15*

*.15 Carbon, High Nickel Chromium Steel*

This quality of steel is intended primarily for case-hardening (Heat Treatment L). It may also be used for structural purposes, but is not first choice for same.

*Heat Treatment L*

After forging or machining—

1. Carbonize at a temperature between 1600° F. and 1750° F. (1650°-1700° F. desired).
2. Cool slowly in the carbonizing mixture.
3. Reheat to 1400°-1500° F.
4. Quench.
5. Reheat to 1300°-1400° F.
6. Quench.
7. Reheat to 250°-500° F. and cool slowly.

*SPECIFICATION No. 33—20*

*.20 Carbon, High Nickel Chromium Steel*

This quality of steel is also intended primarily for case-hardened parts, and when so used demands the most careful treatment (Heat Treatment L).

This quality may also be used for structural purposes, but, as with other alloys, there is little gain over carbon steel unless it be used in a properly heat treated condition. The heat treatment is substantially the same sequence of operations as apply to other nickel chromium steels dealt

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with herein, with such modifications as may be determined by practical experiment.

*Physical Characteristics*

| | Annealed | Heat Treatment M or P |
|---|---|---|
| Yield point or elastic limit, lbs. per sq. in.... | 40,000 to 50,000 | 50,000 to 125,000 |
| Reduction of area..... | 60-45% | 65-30% |
| Elongation in 2"..... | 25-20% | 20- 5% |

## *SPECIFICATION No.* 33—25

### .25 *Carbon, High Nickel Chromium Steel*

This quality of nickel chromium steel is intermediate between that preferred for case-hardening (Steel 33—20) and the next higher quality (Steel 33-30) for heat-treated structural parts.

With the case-hardening treatment (Heat Treatment L) there may be slight modifications necessary.

When properly heat treated this steel will answer for many structural parts. Heat Treatments M and P are recommended.

*Heat Treatment M*

After forging or machining—

1. Reheat to 1375°-1425° F.
2. Quench.
3. Reheat to a temperature between 500° F. and 1250° F. and cool slowly.

A higher refinement of this same treatment is:

*Heat Treatment P*

After forging or machining—

1. Heat to 1450°-1500° F.
2. Quench.
3. Reheat to 1375°-1425° F.
4. Quench.
5. Reheat to a temperature between 500° F. and 1250° F. and cool slowly.

*Physical Characteristics*

| | Annealed | Heat Treatment M or P |
|---|---|---|
| Yield point or elastic limit, lbs. per sq. in.... | 40,000 to 50,000 | 60,000 to 140,000 |
| Reduction of area..... | 60-45% | 65-30% |
| Elongation in 2"..... | 25-20% | 20- 5% |

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## *SPECIFICATION No. 33—30*

### .30 *Carbon, High Nickel Chromium Steel*

This grade of nickel chromium steel is intended primarily for structural parts of the most important character; and should always be heat treated.

This quality is suitable for crank-shafts, axles, spindles, drive-shafts, transmission shafts and, in fact, the most important structural parts of cars.

The heat treatment recommended is the same as in the case of Steel 33—25.

This steel is not intended for case-hardening. If case-hardening be attempted, the highest degree of care must be exercised.

*Physical Characteristics*

| | Annealed | Heat Treatment L or M |
|---|---|---|
| Yield point or elastic limit, lbs. per sq. in.... | 45,000 to 55,000 | 60,000 to 175,000 |
| Reduction of area..... | 55-40% | 60-30% |
| Elongation in 2"..... | 25-15% | 20- 5% |

## *SPECIFICATION No. 33—35*

### .35 *Carbon, High Nickel Chromium Steel*

Substantially the same remarks apply to this steel as apply to Steel 33—30. The carbon content is but five points higher, and the physical characteristics, either annealed or otherwise heat treated, will not differ materially from those given for Steel 33—30, and are repeated below.

This quality should not be used for case-hardening.

*Physical Characteristics*

| | Annealed | Heat Treatment M or P |
|---|---|---|
| Yield point or elastic limit, lbs. per sq. in..... | 45,000 to 55,000 | 60,000 to 175,000 |
| Reduction of area..... | 55-40% | 60-30% |
| Elongation in 2"..... | 25-15% | 20- 5% |

## *SPECIFICATION No. 33—40*

### .40 *Carbon, High Nickel Chromium Steel*

This quality of steel is suitable for structural parts where unusual strength is demanded. Higher elastic limit is possible under a given treatment than with material like Steels 33—30 or 33—35. The toughness will not be quite as great, but this does not bar the material from uses where toughness is not the controlling factor and where strength is.

Heat Treatment P is recommended.

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This steel should be thoroughly annealed for machining.
This quality of steel should not be case-hardened.

*Physical Characteristics*

| | Annealed | Heat Treatment P |
|---|---|---|
| Yield point or elastic limit, lbs. per sq. in... | 50,000 to 60,000 | 65,000 to 200,000 |
| Reduction of area..... | 50-40% | 50-20% |
| Elongation in 2"..... | 25-15% | 15- 2% |

## *SPECIFICATION No. 33—45*

### .45 *Carbon, High Nickel Chromium Steel*

The use of this steel is largely for gears, where extreme strength and hardness are necessary. The carbon is sufficiently high to cause the material, in the presence of chromium and nickel, to become hard enough to make a good gear when quenched, without case-hardening (carbonizing).

This steel is difficult to forge. During the forging operation it should be kept at a thoroughly plastic heat and not hammered or worked after dropping to ordinary forging temperatures; otherwise cracking is liable to follow. The steel also becomes so very hard as to forge with great difficulty. On the other hand, too high a temperature is not advisable, as the steel becomes red-short and breaks. In brief, the forging temperature limits are narrow and this steel must be reheated more frequently than any of the other steels dealt with in this report.

To heat treat for gears, either Heat Treatment Q or R is used, the latter giving the best results:

*Heat Treatment Q*

After forging—

1. Reheat to 1475°-1525° F. (Hold at this temperature one-half hour to insure thorough heating.)
2. Cool slowly.
3. Reheat to 1450°-1500° F.
4. Quench.
5. Reheat to 250°-550° F. and cool slowly.

This steel should be thoroughly annealed for machining—Operations 1 and 2.

The final drawing operation must be conducted at a heat which will produce the proper degree of hardness. The desired Brinell hardness for a gear is between 430 and 470, the corresponding Shore hardness being from 75 to 85.

This quality of steel should not be case-hardened.

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*Physical Characteristics*

| | Annealed | Heat Treatment Q |
|---|---|---|
| Yield point or elastic limit, lbs. per sq. in.... | 50,000 to 60,000 | 150,000 to 250,000 |
| Reduction of area..... | 50-40% | 25-15% |
| Elongation in 2"..... | 25-15% | 15- 2% |

*Heat Treatment R*

After forging—

1. Heat to 1500°-1550° F.
2. Quench in oil.
3. Reheat to 1200°-1300° F. (Hold at this temperature three hours.)
4. Cool slowly.
5. Machine.
6. Reheat to 1350°-1450° F.
7. Quench in oil.
8. Reheat to 250°-500° F. and cool slowly.

## NICKEL CHROMIUM VANADIUM STEELS

*SPECIFICATIONS* 41— *and* 42—

The heat treatments and remarks as to application for this class of steels are essentially the same as for classes 31— and 32—. The physical characteristics obtained are very similar.

## CHROMIUM STEELS

*SPECIFICATIONS* 51— *and* 52—

The use of this type of steel is restricted almost entirely to ball and roller bearings. The physical characteristic most desired is extreme hardness. As the automobile manufacturer rarely works this quality of steel, no further remarks are given here.

## CHROMIUM VANADIUM STEELS

*SPECIFICATION No.* 61—15

.15 *Carbon, Chromium Vanadium Steel*

Chromium vanadium steel has found much usage in automobile parts, particularly springs, axles, driving-shafts and gears. It is used interchangeably with carbon steel, nickel steel and nickel chromium steel.

Steel 61—15 is provided to furnish a quality that is highly suitable for carbonizing purposes, such as gears and case-hardened parts of importance.

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Properly treated parts of this quality will be found to possess an extremely high degree of strength and toughness.

This steel is also available for structural purposes, but should not be selected for such purposes when ordering materials. Better results are obtainable from some of the other qualities to be mentioned.

The treatment recommended for case-hardening follows, viz.:

*Heat Treatment S*

After forging or machining—

1. Carbonize at a temperature between 1600° F. and 1750° F. (1650°-1700° F. desired).
2. Cool slowly in the carbonizing mixture.
3. Reheat to 1650°-1750° F.
4. Quench.
5. Reheat to 1475°-1550° F.
6. Quench.
7. Reheat to 250°-550° F. and cool slowly.

The high initial quenching temperature of this steel is noteworthy, that is, something over 1600° F. This feature is different from other steels referred to in this report and characteristic of chromium vanadium steel.

The heat for second quench (Operation 5) should be conducted at the lowest possible temperature that will harden the exterior carbonized surface. Practical experiment will develop the best temperature for local conditions in any hardening room.

*Physical Characteristics*

| | Annealed | Heat Treatment T |
|---|---|---|
| Yield point or elastic limit, lbs. per sq. in.... | 35,000 to 45,000 | 50,000 to 90,000 |
| Reduction of area..... | 70-50% | 70-40% |
| Elongation in 2"..... | 30-25% | 25-10% |

## *SPECIFICATION* 61—20

### .20 *Carbon, Chromium Vanadium Steel*

This quality is also primarily for case-hardening. It is used for the most important case-hardened parts; that is, case-hardened shafts, gears and the like.

This steel may also be used in a heat treated condition for structural purposes, but for such work some of the specifications following are to be preferred, particularly where higher strength is desired.

The case-hardening treatment recommended is that covered by Heat Treatment S.

For structural purposes the following heat treatment is recommended:

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*Heat Treatment T*

After forging or machining—

1. Heat to 1650°-1750° F.
2. Quench.
3. Reheat to some temperature between 500° F. and 1300° F. and cool slowly.

*Physical Characteristics*

| | Annealed | Heat Treatment 16 |
|---|---|---|
| Yield point or elastic limit, lbs. per sq. in.... | 40,000 to 50,000 | 55,000 to 100,000 |
| Reduction of area..... | 65-50% | 65-45% |
| Elongation in 2"..... | 30-20% | 25-10% |

## *SPECIFICATION* 61—25

### .25 *Carbon, Chromium Vanadium Steel*

The difference between this and the preceding steel is very slight and they may be used interchangeably for structural purposes. This steel may be case-hardened but is not first choice for this purpose.

The physical characteristics may be considered as practically the same as given for Steel 61—20.

*Physical Characteristics*

| | Annealed | Heat Treatment T |
|---|---|---|
| Yield point or elastic limit, lbs., per sq. in... | 40,000 to 50,000 | 55,000 to 100,000 |
| Reduction of area..... | 65-50% | 65-45% |
| Elongation in 2"..... | 30-20% | 25-10% |

## *SPECIFICATION No.* 61—30

### .30 *Carbon, Chromium Vanadium Steel*

This quality of steel is intermediate in the carbon range and may be used interchangeably with Steel 61—25 for structural purposes. It should not to be used for case-hardening. When treated as recommended by Heat Treatment T possesses a high degree of combined strength and toughness.

*Physical Characteristics*

| | Annealed | Heat Treatment T |
|---|---|---|
| Yield point or elastic limit, lbs. per sq. in.... | 45,000 to 55,000 | 60,000 to 150,000 |
| Reduction of area..... | 60-50% | 55-25% |
| Elongation in 2"..... | 25-20% | 15- 5% |

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## *SPECIFICATION No. 61—35*

### .35 *Carbon, Chromium Vanadium Steel*

This specification provides a first-rate quality of steel for structural parts that are to be heat treated. The fatigue-resisting (endurance) qualities of this material are excellent.

*Physical Characteristics*

| | Annealed | Heat Treatment T |
|---|---|---|
| Yield point or elastic limit, lbs. per sq. in.... | 45,000 to 55,000 | 60,000 to 150,000 |
| Reduction of area..... | 60-50% | 55-25% |
| Elongation in 2"..... | 25-20% | 15- 5% |

## *SPECIFICATION No. 61—40*

### .40 *Carbon, Chromium Vanadium Steel*

This is a very good quality of steel to be selected where a high degree of strength is desired, coupled with a good measure of toughness. Its fatigue-resisting qualities are very high, and it is a first-class material for high duty shafts.

Heat Treatment T is recommended:

*Physical Characteristics*

| | Annealed | Heat Treatment T |
|---|---|---|
| Yield point or elastic limit, lbs. per sq. in..... | 50,000 to 60,000 | 65,000 to 175,000 |
| Reduction of area..... | 55-45% | 50-15% |
| Elongation in 2"..... | 25-15% | 15- 2% |

## *SPECIFICATION No. 61-45*

### .45 *Carbon, Chromium Vanadium Steel*

This quality of steel contains sufficient carbon in combination with chromium and vanadium to harden to a considerable degree when quenched at a proper temperature, and may be used for gears and springs.

For structural parts where exceedingly high strength is desirable Heat Treatment T should be followed.

For gears this steel should be annealed after forging, and before machining, the anneal to consist of operations 1 and 2 of the following:

*Heat Treatment U*

1. Heat to 1525°-1600° F. (Hold for about ½ hour.)
2. Cool slowly.
3. Reheat to 1650°-1700° F.

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4. Quench.
5. Reheat to 350°-550° F. and cool slowly.

This last drawing operation may be modified to obtain any desired hardness.

| *Physical Characteristics* | Annealed | Heat Treatment U |
|---|---|---|
| Yield point or elastic limit, lbs. per sq in.... | 55,000 to 65,000 | 150,000 to 200,000 |
| Reduction of area..... | 55-40% | 25-10% |
| Elongation in 2"..... | 25-15% | 10- 2% |

*SPECIFICATION No.* 61-50

.50 *Carbon, Chromium Vanadium Steel*

Substantially the same remarks as made in regard to Steel 61—45 apply to this quality. In this grade, however, we also find a material that is suitable for springs. With a proper sequence of heating, quenching and drawing, very high elastic limits are obtained.

For spring material Heat Treatment U is recommended, except that the last drawing (Operation 5) will be carried farther—probably from 700°-1100° F. This final drawing temperature will have to vary with the section of material being handled, whether light spiral springs or heavy flat springs.

*Physical Characteristics*

| | Annealed | Heat Treatment U |
|---|---|---|
| Yield point or elastic limit, lbs. per sq. in.... | 60,000 to 70,000 | 150,000 to 225,000 |
| Reduction of area..... | 50-35% | 35-15% |
| Elongation in 2"..... | 20-15% | 10- 2% |

## SILICO-MANGANESE STEEL

*SPECIFICATION No.* 92-50

*Silico-Manganese Steel*

This steel stands in a class by itself. It has been more or less standardized by usage as a spring steel. It is also used somewhat for gears. All parts made of this steel should be heat treated.

For structural parts the treatment should be:

*Heat Treatment V*

After forging or machining—

1. Heat to 1650°-1750° F.
2. Quench.
3. Reheat to a temperature between 500° F. and 1200° F. and cool slowly.

Suitable temperatures for any given thickness of piece, and the character of the quenching medium must be determined experimentally.

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When used for springs this material may be treated as above, with proper modification as to drawing temperature, with the probability that 800° F. as a drawing temperature will give about the proper characteristics.

*Physical Characteristics*

| | Annealed | Heat Treatment V |
|---|---|---|
| Yield point or elastic limit, lbs. per sq. in..... | 55,000 to 65,000 | 60,000 to 180,000 |
| Reduction of area..... | 45-30% | 40-10% |
| Elongation in 2"..... | 25-20% | 20- 5% |

## VALVE METALS

*SPECIFICATIONS Nos. 296 and 231*

### *Valve Metals*

For valves, and especially exhaust valves, high-speed tool steel is now being used. The exact analysis of this grade of tool steel is not important, as there are many kinds available, all more or less alike in composition. The chief characteristics of such steels are the tungsten (18-20 per cent.) and chromium (4-10 per cent.) contents. This quality of steel has proved very successful in the case of motorcycle valves, where the heat is intense.

## IRON CASTINGS

### *Gray Iron Castings*

The use of specifications for cast-iron in the present state of the foundry art is not very easy. The foundryman, if he is not accustomed to work to analysis, will object, although his iron may be within the specifications given 90 per cent. of the time. Moreover, if there are any defective cylinders he will be likely to lay it to the composition of the iron, whereas the fault may lie in his foundry methods, apart from composition.

Consequently these specifications should be used as indicating the ideal mixture—something for the foundryman to work to, even though he may not be willing to guarantee the analysis.

If trouble is experienced with cylinders, analysis of samples of the iron will show whether or not the composition is somewhere near what it should be. If the composition is very far from the specification here given, the purchaser will be justified in putting up strenuous objection.

Iron in accordance with this specification will be strong and reasonably close-grained in the thicknesses cast, and one that wears well.

### *Malleable Iron*

The remarks made in connection with the gray iron specification apply even more strongly to malleable iron. Iron of the composition

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given, properly annealed, will make a strong and tough casting; but improperly annealed it will not make a good casting.

Castings that are received brittle may be so from two causes: first, unsuitable mixture of iron; second, incomplete annealing. Consequently, if brittle castings are received, they should be analyzed, and if the analysis is correct, then it is certain that the annealing operation was not properly performed.

# LIST OF HEAT TREATMENTS

*Heat Treatment A*

After forging or machining—

1. Carbonize to a temperature between 1600° F. and 1750° F. (1650°-1700° F. desired).
2. Cool slowly or quench.
3. Reheat to 1500°-1550° F. and quench.

*Heat Treatment B*

After forging or machining—

1. Carbonize at a temperature between 1600° F. and 1750° F. (1650°-1700° F. desired).
2. Cool slowly in the carbonizing mixture.
3. Reheat to 1500°-1550° F.
4. Quench.
5. Reheat to 1400°-1450° F.
6. Quench.
7. Draw in hot oil at a temperature which may vary from 300° 450° F., depending upon the degree of hardness desired.

*Heat Treatment C*

After forging or machining—

1. Heat to 1475°-1525° F.
2. Quench.
3. Reheat to 600°-1200° F. and cool slowly.

*Heat Treatment D*

After forging or machining—

1. Heat to 1500°-1550° F.
2. Quench.
3. Reheat to 1450°-1500° F.
4. Quench.
5. Reheat to 600°-1200° F. and cool slowly.

*Heat Treatment E*

After forging or machining—

1. Heat to 1500°-1550° F.
2. Cool slowly.

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3. Reheat to 1450°-1500° F.
4. Quench.
5. Reheat to 600°-1200° F. and cool slowly.

*Heat Treatment F*

After shaping or coiling—

1. Heat to 1450°-1500° F.
2. Quench in oil.
3. Reheat to 400°-800° F., in accordance with degree of temper desired, and cool slowly.

*Heat Treatment G*

After forging or machining—

1. Carbonize at a temperature between 1600° F. and 1750° F. (1650°-1700° F. desired).
2. Cool slowly in the carbonizing material.
3. Reheat to 1500°-1550° F.
4. Quench.
5. Reheat to 1300°-1400° F.
6. Quench.
7. Reheat to a temperature from 250°-500° F. (in accordance with the necessities of the case, and cool slowly.

*Heat Treatment H*

After forging or machining—

1. Heat to 1500°-1550° F.
2. Quench.
3. Reheat to 600°-1200° F. and cool slowly.

*Heat Treatment K*

After forging or machining—

1. Heat to 1500°-1550° F.
2. Quench.
3. Reheat to 1300°-1400° F.
4. Quench.
5. Heat to 600°-1200° F. and cool slowly.

*Heat Treatment L*

After forging or machining—

1. Carbonize at a temperature between 1600° F. and 1750° F. (1650°-1700° F. desired).
2. Cool slowly in the carbonizing mixture.
3. Reheat to 1400°-1500° F.
4. Quench.
5. Reheat to 1300°-1400° F.
6. Quench.
7. Heat to 250°-500° F. and cool slowly.

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*Heat Treatment M*

After forging or machining—

1. Heat to 1450°-1500° F.
2. Quench.
3. Reheat to a temperature between 500° F. and 1250° F. and cool slowly.

*Heat Treatment P*

After forging or machining—

1. Heat to 1450°-1500° F.
2. Quench.
3. Reheat to 1375°-1425° F.
4. Quench.
5. Reheat to a temperature between 500° F. and 1250° F. and cool slowly.

*Heat Treatment Q*

After forging—

1. Reheat to 1475°-1525° F. (Hold at this temperature one-half hour to insure thorough heating.)
2. Cool slowly.
3. Reheat to 1450°-1500° F.
4. Quench.
5. Reheat to 250°-500° F. and cool slowly.

*Heat Treatment R*

After forging—

1. Heat to 1500°-1550° F.
2. Quench in oil.
3. Reheat to 1200°-1300° F. (Hold at this temperature three hours.
4. Cool slowly.
5. Machine.
6. Reheat to 1350°-1450° F.
7. Quench in oil.
8. Reheat to 250°-500° F. and cool slowly.

*Heat Treatment S*

After forging or machining—

1. Carbonize at a temperature between 1600° F. and 1750° F. (1650°-1700° F. desired).
2. Cool slowly in the carbonizing mixture.
3. Reheat to 1650°-1750° F.
4. Quench.
5. Reheat to 1475°-1550° F.
6. Quench.
7. Reheat to 250°-550° F. and cool slowly.

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*Heat Treatment T*

After forging or machining—

1. Heat to 1650°-1750° F.
2. Quench.
3. Reheat to some temperature between 500° F. and 1300° F. and cool slowly.

*Heat Treatment U*

After forging—

1. Heat to 1525°-1600° F. (Hold for about one-half hour.)
2. Cool slowly.
3. Reheat to 1650°-1700° F.
4. Quench.
5. Reheat to 350°-550° F. and cool slowly.

*Heat Treatment V*

After forging or machining—

1. Heat to 1650°-1750° F.
2. Quench.
3. Reheat to a temperature between 500° F. and 1200° F. and cool slowly.

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**The data and figures appearing in the following tables have been taken from results obtained in actual tests. They must not be used as representing normal results. Some of them are very extraordinary and abnormal.***

*Note added as result of discussion at meeting of the Society, June, 1913.

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## PHYSICAL CHARACTERISTICS OF CARBON STEELS

| Spec. | Treatment | Elastic Limit | Red. of Area | Elong. in 2" | Brinell Hardness | Shore Hardness |
|---|---|---|---|---|---|---|
| 10–10 | ..... | ..... | .... | .... | ..... | .... |
| 10–15 | ..... | ..... | .... | .... | ..... | .... |
| 10–20 | Annealed..... | 36,000 | 70.3 | 40.5 | 100 | .... |
| 10–20 | C-500° F. Draw..... | 77,000 | 55.5 | 14.5 | 189 | .... |
| 10–20 | C-1200° F. Draw..... | 50,000 | 65.5 | 32.0 | ..... | .... |
| 10–25 | Annealed..... | 44,000 | 56.0 | 33.5 | 126 | 21 |
| 10–25 | C-750° F. Draw..... | 70,000 | 61.1 | 21.5 | 196 | 32 |
| 10–25 | C-1100° F. Draw..... | 58,500 | 67.0 | 28.5 | 170 | 27 |
| 10–30 | Annealed..... | 38,500 | 51.9 | 30.0 | 156 | 27 |
| 10–30 | C-500° F..... | 85,000 | 17.0 | 7.5 | 255 | 38 |
| 10–30 | C-1100° F..... | 66,500 | 51.1 | 22.0 | 207 | 33 |
| 10–30 | C-500° F..... | 104,000 | 54.0 | 9.5 | 276 | .... |
| 10–30 | C-1200° F..... | 58,000 | 71.4 | 34.3 | 160 | .... |
| 10–35 | Annealed..... | 43,000 | 50.0 | 27.0 | 158 | .... |
| 10–40 | Annealed..... | 41,000 | 46.0 | 21.0 | ..... | .... |
| 10–45 | Annealed..... | 48,000 | 50.6 | 29.5 | 143 | 22 |
| 10–45 | Annealed..... | 49,000 | 35.0 | 21.5 | 166 | .... |
| 10–45 | C-750° F..... | 94,000 | 49.0 | 17.0 | 255 | 40 |
| 10–45 | C-1100° F..... | 71,000 | 57.3 | 23.0 | 207 | 30 |
| 10–45 | C-850° F..... | 85,500 | 34.0 | 14.5 | 286 | 42 |
| 10–45 | C-1100° F..... | 76,500 | 43.5 | 18.0 | 241 | 37 |
| 10–45 | C-1200° F..... | 75,000 | 59.7 | 23.0 | 215 | .... |
| 10–95 | Annealed..... | 50,000 | 37.5 | 21.5 | 187 | 29 |
| 10–95 | F-750° F..... | 150,000 | 19.5 | 8.5 | 402 | 61 |
| 10–95 | F-1100° F..... | 103,000 | 29.0 | 14.0 | 277 | 48 |

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## PHYSICAL CHARACTERISTICS OF NICKEL STEELS

| Spec. | Treatment | Elastic Limit | Red. of Area | Elong. in 2″ | Brinell Hardness | Shore Hardness |
|---|---|---|---|---|---|---|
| 23–10 | ..... | ..... | .... | .... | ..... | .... |
| 23–15 | ..... | ..... | .... | .... | ..... | .... |
| 23–20 | Annealed..... | 57,500 | 65.0 | 30.0 | 143 | .... |
| 23–20 | Annealed..... | 43,000 | 62.0 | 27.0 | 170 | .... |
| 23–20 | H-600F..... | 140,000 | 61.0 | 14.0 | 330 | .... |
| 23–20 | H-1000F..... | 95,000 | 72.3 | 20.0 | 216 | .... |
| 23–20 | H-600F..... | 155,000 | 59.5 | 13.5 | 340 | .... |
| 23–25 | Annealed..... | ..... | .... | .... | ..... | .... |
| 23–25 | H-600F..... | 175,000 | 58.5 | 13.5 | 394 | .... |
| 23–25 | H-1000F..... | 107,000 | 71.3 | 21.5 | 235 | .... |
| 23–25 | H-600F..... | 180,500 | 60.5 | 13.5 | 405 | .... |
| 23–25 | H-1000F..... | 115,000 | 69.8 | 20.0 | 267 | .... |
| 23–30 | Annealed..... | 63,000 | 63.0 | 27.0 | 163 | .... |
| 23–30 | H-600F..... | 187,000 | 57.5 | 13.0 | 405 | .... |
| 23–30 | H-750F..... | 123,000 | 57.3 | 15.0 | 269 | 41 |
| 23–30 | H-1100F..... | 87,000 | 67.7 | 25.0 | 207 | 30 |
| 23–30 | H-1000F..... | 120,000 | 62.5 | 17.5 | 288 | .... |
| 23–35 | Annealed..... | 62,500 | 58.0 | 26.5 | 165 | .... |
| 23–35 | H-1200F..... | 101,000 | 66.9 | 24.0 | 220 | .... |
| 23–35 | H-600F..... | 200,000 | 57.5 | 12.3 | 415 | .... |
| 23–40 | Annealed..... | 65,000 | 57.3 | 27.0 | 168 | .... |
| 23–40 | H-1200F..... | 104,000 | 65.4 | 24.0 | 225 | .... |

## PHYSICAL CHARACTERISTICS OF LOW NICKEL CHROMIUM STEELS

| Spec. | Treatment | Elastic Limit | Red. of Area | Elong. in 2″ | Brinell Hardness | Shore Hardness |
|---|---|---|---|---|---|---|
| 31–10 | ..... | ..... | .... | .... | ..... | .... |
| 31–15 | ..... | ..... | .... | .... | ..... | .... |
| 31–20 | Annealed..... | 41,000 | 54.0 | 32.0 | 153 | 21 |
| 31–20 | M-600F..... | 150,000 | 20.0 | 5.0 | 351 | 56 |
| 31–20 | M-1200F..... | 90,000 | 61.0 | 16.0 | 228 | 35 |
| 31–25 | ..... | ..... | .... | .... | ..... | .... |
| 31–30 | Annealed..... | 57,000 | 55.0 | 26.0 | 172 | 27 |
| 31–30 | M-600F..... | 171,000 | 25.0 | 7.5 | 384 | 60 |

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## PHYSICAL CHARACTERISTICS OF LOW NICKEL CHROMIUM STEELS (Continued)

| Spec. | Treatment | Elastic Limit | Red. of Area | Elong. in 2″ | Brinell Hardness | Shore Hardness |
|---|---|---|---|---|---|---|
| 31–30 | M-1200F | 95,000 | 62.5 | 21.0 | 242 | 38 |
| 31–35 | ..... | ..... | .... | .... | ..... | .... |
| 31–40 | Annealed | 61,000 | 53.0 | 24.0 | 192 | 34 |
| 31–40 | M-600F | 195,000 | 32.0 | 10.0 | 418 | 63 |
| 31–40 | M-1200F | 100,000 | 65.0 | 21.0 | 257 | 47 |

## PHYSICAL CHARACTERISTICS OF MEDIUM NICKEL CHROMIUM STEELS

| Spec. | Treatment | Elastic Limit | Red. of Area | Elong. in 2″ | Brinell Hardness | Shore Hardness |
|---|---|---|---|---|---|---|
| 32–10 | ..... | ..... | .... | .... | ..... | .... |
| 32–15 | ..... | ..... | .... | .... | ..... | .... |
| 32–20 | Annealed | 55,000 | 69.2 | 39.5 | 170 | .... |
| 32–20 | M-400F | 170,000 | 51.0 | 13.5 | 400 | .... |
| 32–25 | ..... | ..... | .... | .... | ..... | .... |
| 32–30 | ..... | ..... | .... | .... | ..... | .... |
| 32–35 | Annealed | 66,000 | 53.0 | 26.0 | 196 | 30 |
| 32–35 | M-750F | 184,000 | 47.0 | 12.5 | 402 | 62 |
| 32–35 | M-1100F | 127,000 | 57.3 | 20.0 | 286 | 47 |
| 32–40 | Annealed | 60,000 | 66.9 | 29.5 | 175 | .... |
| 32–40 | M-400F | 230,000 | 35.0 | 9.5 | 490 | .... |
| 32–40 | M-500F | 186,000 | 4.0 | 4.6 | 532 | 66 |
| 32–40 | M-850F | 156,000 | 45.5 | 12.0 | 418 | 59 |
| 32–40 | M-1100F | 125,000 | 57.8 | 18.0 | 321 | 47 |
| 32–40 | M-1200F | 150,000 | 57.3 | 16.5 | 325 | .... |
| 32–45 | Annealed | ..... | .... | .... | ..... | .... |
| 32–45 | M-850F | 165,000 | 39.0 | 11.5 | 430 | 60 |
| 32–45 | M-1100F | 130,500 | 54.1 | 17.5 | 340 | 48 |
| 32–50 | Annealed | 62,000 | 54.6 | 25.0 | 180 | .... |
| 32–50 | M-400F | 240,000 | 33.0 | 6.0 | 495 | .... |
| 32–50 | M-500F | 234,000 | 33.8 | 9.0 | 395 | 65 |
| 32–50 | M-600F | 215,000 | 37.0 | 8.0 | 446 | .... |
| 32–50 | M-700F | 215,900 | 39.8 | 10.0 | 373 | 59 |
| 32–50 | M-900F | 186,000 | 46.9 | 13.0 | 330 | 55 |

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## PHYSICAL CHARACTERISTICS OF HIGH NICKEL CHROMIUM STEELS

| Spec. | Treatment | Elastic Limit | Red. of Area | Elong. in 2″ | Brinell Hardness | Shore Hardness |
|---|---|---|---|---|---|---|
| 33–30 | Annealed | ..... | .... | .... | ..... | .... |
| 33–30 | M-500F | 185,000 | 39.0 | 13.0 | 477 | 62 |
| 33–30 | M-850F | 149,000 | 54.7 | 15.5 | 418 | 59 |
| 33–30 | M-950F | 135,000 | 58.6 | 17.5 | 375 | 55 |
| 33–30 | M-1100F | 119,000 | 62.3 | 21.0 | 302 | 48 |
| 33–35 | Annealed | ..... | .... | .... | ..... | .... |
| 33–35 | M-700F | 187,500 | 51.4 | 12.0 | 330 | 51 |
| 33–35 | M-900F | 170,000 | 57.9 | 14.5 | 312 | 50 |
| 33–35 | M-1100F | 154,000 | 56.0 | 16.0 | ..... | .... |
| 33–35 | M-1200F | 120,000 | 61.0 | 18.5 | ..... | .... |

## PHYSICAL CHARACTERISTICS OF CHROMIUM VANADIUM STEELS

| Spec. | Treatment | Elastic Limit | Red. of Area | Elong. in 2″ | Brinell Hardness | Shore Hardness |
|---|---|---|---|---|---|---|
| 61–10 | ..... | ..... | .... | .... | ..... | .... |
| 61–15 | ..... | ..... | .... | .... | ..... | .... |
| 61–20 | Annealed | 40,000 | 69.0 | 36.0 | 150 | .... |
| 61–20 | T-600F (oil) | 145,000 | 55.0 | 12.0 | 390 | .... |
| 61–20 | T-600F (water) | 180,000 | 51.5 | 12.0 | 385 | .... |
| 61–20 | T- | ..... | .... | .... | ..... | .... |
| 61–25 | Annealed | 61,000 | 66.4 | 34.8 | 149 | .... |
| 61–25 | T-750F | 155,000 | 51.0 | 13.0 | 418 | .... |
| 61–25 | T-1200F | 99,000 | 69.9 | 30.0 | 277 | .... |
| 61–30 | Annealed | 45,000 | 69.2 | 35.0 | 155 | .... |
| 61–30 | T-600F | 200,000 | 51.9 | 10.5 | 429 | .... |
| 61–30 | T-850F | 180,400 | 43.5 | 10.0 | 430 | 54 |
| 61–30 | T-1300F | 101,000 | 64.1 | 20.0 | 255 | 39 |
| 61–35 | ..... | ..... | .... | .... | ..... | .... |
| 61–40 | Annealed | 50,000 | 68.0 | 34.0 | 158 | .... |
| 61–40 | T-800F | 200,000 | 48.0 | 11.0 | 435 | .... |
| 61–40 | T-1200F | 120,000 | 53.0 | 20.0 | 270 | .... |

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## PHYSICAL CHARACTERISTICS OF CHROMIUM VANADIUM STEELS —Continued

| Spec. | Treatment | Elastic Limit | Red. of Area | Elong in 2″ | Brinell Hardness | Shore Hardness |
|---|---|---|---|---|---|---|
| 61–45 | Annealed | 74,000 | 56.7 | 27.0 | 196 | 30 |
| 61–45 | Annealed | 64,000 | 68.1 | 25.5 | 217 | 30 |
| 61–45 | T-750F | 208,000 | 29.0 | 9.0 | 460 | 70 |
| 61–45 | T-850F | 198,000 | 45.5 | 11.5 | 477 | 61 |
| 61–45 | T-900F | 182,000 | 45.0 | 12.0 | 387 | 60 |
| 61–45 | T-1100F | 162,000 | 49.0 | 14.5 | 340 | 54 |
| 61–45 | T-1100F | 156,000 | 45.0 | 15.0 | 340 | 54 |
| 61–45 | T-1300F | 130,000 | 53.3 | 18.5 | 332 | 49 |
| 61–50 | Annealed | 55,500 | 67.0 | 34.0 | 196 | 32 |
| 61–50 | Annealed | 52,000 | 67.7 | 30.5 | 163 | .... |
| 61–50 | Annealed | 63,600 | 61.5 | 25.8 | 187 | .... |
| 61–50 | T-750F | 248,600 | 27.3 | 8.0 | 532 | 71 |
| 61–50 | T-750F | 239,000 | 17.0 | 6.5 | 444 | .... |
| 61–50 | T-800F | 220,000 | 30.0 | 8.5 | 440 | .... |
| 61–50 | T-800F | 200,000 | 50.0 | 9.5 | 447 | .... |
| 61–50 | T-1100F | 179,300 | 37.0 | 13.0 | 402 | 58 |
| 61–50 | T-1200F | 150,000 | 54.0 | 17.0 | 280 | .... |

## PHYSICAL CHARACTERISTICS OF SILICO-MANGANESE STEEL

| Spec. | Treatment | Elastic Limit | Red. of Area | Elong. in 2″ | Brinell Hardness | Shore Hardness |
|---|---|---|---|---|---|---|
| 92–50 | Annealed | 57,000 | 47.5 | 24.2 | ..... | .... |
| 92–50 | V-800F draw | 198,700 | 21.0 | 8.5 | 418 | 63 |
| 92–50 | V-800F draw | 208,000 | 28.6 | 7.5 | 450 | .... |

## CHROMIUM NICKEL VANADIUM STEELS

| | | | | | | |
|---|---|---|---|---|---|---|
| 41–25 | Annealed | 58,500 | 65.9 | 32.0 | 156 | 25 |
| 41–25 | H-500F draw | 159,500 | 40.5 | 11.5 | 364 | 49 |
| 41–25 | H-850F draw | 127,000 | 58.6 | 16.0 | 321 | 45 |
| 41–25 | H-950F draw | 122,000 | 61.1 | 17.0 | 302 | 40 |
| 41–25 | H-1100F draw | 107,500 | 63.0 | 19.5 | 269 | 39 |
| 42–35 | Annealed | 67,500 | 59.8 | 27.0 | 207 | 31 |
| 42–35 | M-750F draw | 209,000 | 40.5 | 9.5 | 444 | 68 |
| 42–35 | M-950F draw | 178,000 | 50.0 | 13.5 | 387 | 61 |
| 42–35 | M-1100F draw | 156,000 | 53.3 | 16.0 | 340 | 52 |

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# BIBLIOGRAPHY OF STEEL*

## COMPOSITION AND HEAT TREATMENT

Annealing and Heat Treating Steel Alloys. *Mechanical Engineer,* Manchester, England, Vol. 20, p. 739, 1907.

Heat Treatment Experiments with Chrome Vanadium Steel. By H. R. Sankey and J. K. Smith. Institution of Mechanical Engineers, *Proceedings,* 1904, pt. 4, p. 1235.

Treated Steel for High Service. By J. H. Baker. *Iron Age,* Vol. 84, p. 1632-36, 1909.

Notes on the Annealing of Medium Carbon Steel. By William Campbell. American Society for Testing Materials, *Proceedings,* Vol. 9, p. 370, 1909.

Report of Committee F, on Heat Treatment of Iron and Steel. American Society for Testing Materials *Proceedings,* Vol. 9, p. 214, 1909.

Heat Treatment of Spring Steel. By Lawford H. Fry. International Association for Testing Materials. Copenhagen (report), 1909.

Heat Treatment Study of Bessemer Steels. By Andrew McWilliam and Ernest J. Barnes. Iron and Steel Institute *Journal,* 1909, pt. 1, p. 348.

Notes on the Production and Thermal Treatment of Steel in Large Masses. By Cosmo Johns. Iron and Steel Institute *Journal,* 1904, pt. 1, p. 61.

Heat Treatment of Steels Containing Fifty Hundredths and Eighty Hundredths Per Cent. of Carbon. By C. E. Corson. American Institute of Mining Engineers *Transactions,* Vol. 37, p. 388, 1907.

Pyrometry and the Heat Treatment of Steel. By Henry M. Howe. American Institute of Mining Engineers *Transactions,* Vol. 24, p. 746, 1894.

A Study of the Effect of Heat Treatment on Crucible Steel Containing 1 Per Cent. Carbon. By George W. Sargent. American Institute of Mining Engineers *Transactions,* Vol. 31, p. 303, 1904.

Microstructure of Steel and the Current Theories of Hardening. By Albert Sauveur. American Institute of Mining Engineers *Transactions,* Vol. 26, p. 863, 1896.

On the Heat Treatment of Some High Carbon Steels. By William Campbell. American Chemical Society *Journal,* Vol. 28, p. 1304, 1906.

An Experimental Double Muffle Gas Heating Furnace for Studying the Laws of the Heat Treatment of Steel. By Henry M. Howe. American Society for Testing Materials, Vol. 6, p. 202, 1906.

Alterations of Steel in Heat Treating. By J. E. Storey. *American Machinist,* pt. 1, p. 277, 1908.

Heat Treatment of Carbon Steel. By J. H. Gill. *American Machinist,* pt. 2, p. 844, 1908.

*Search of Library of the Engineering Societies, 29 West Thirty-ninth street, New York City, May 17, 1913, for Society of Automobile Engineers.

Digitized by Google

Heat Treatment of Steel Rails. By William Metcalf. Engineers' Society of Western Pennsylvania *Proceedings,* Vol. 24, p. 135, 1908.

Manganese Steel. By W. S. Potter. Western Society of Engineers *Journal,* Vol. 14, p. 212, 1909 (two pages on heat treatment).

High-Speed Steel and Its Heat Treatment. *Mechanical Engineer,* Manchester, England, Vol. 25, p. 537, 1910. Abstract of article by W. G. Smith, of Armour Institute of Technology, published in the *Armour Engineer.*

Heat Treatment of Steel. *Mechanical Engineer,* Manchester, England, Vol. 23, p. 305, 1909. Abstract of paper read by F. C. Moorwood before the Sheffield Society of Engineers and Metallurgists on "Metallic salts and their application in the heat treatment of steel."

Untersuchungen über den Einfluss der Wärme auf die Harte der Metalle. By Alfred Kürth. *Zeitschrift des Vereins deutscher Ingenieure,* Vol. 53, p. 85, 209, 1909.

Heat Treatment of High-Speed Tools. By C. P. Berg. Western Society of Engineers *Journal,* Vol. 15, p. 729-54; discussion, p. 755-64.

Transformations of Steel Within the Limits of the Temperature Employed in Heat Treatment. By L. Grenet. Iron and Steel Institute *Journal,* 1911, pt. 2, p. 13-53; discussion, p. 54-75.

Heat Treatment of Acid and Basic Open-Hearth Steel of Similar Composition. By Henry Fay. American Society for Testing Materials. *Proceedings,* 1911, p. 417-19; discussion, p. 420-21. Reprint in *Iron Age,* Vol. 88, p. 25, 1911.

Study of the Heat Treatment of Some Low Carbon Nickel Steels. By Henry Fay and J. M. Bierer. American Society for Testing Materials, Vol. 11, p. 422-27, 1911.

Heat Treatment of a Steel Containing 3.15 Per Cent. Nickel and 0.27 Per Cent. Carbon. By William Campbell and H. B. Allen. American Society of Testing Materials, Vol. 11, p. 428-38, 1911.

Ueber die Wärmebehandlung der Stähle. By H. Hanemann. *Stahl und Eisen,* Vol. 31, p. 1365-73, 1911. Abstract in Iron and Steel Institute *Journal,* 1911, pt. 2, p. 598-600.

Heat Treatment of Steel Under Conditions of Steel Works Practice. By Alfred Campion. Iron and Steel Institute *Journal,* 1903, pt. 1, p. 378-451; discussion, p. 452-56.

Notes on the Heat Treatment of Steel. By Henry Souther. *Iron Age,* Jan. 4, 1912, p. 22-3.

Heat Treatment of Steel. A discussion of equipment and methods employed. By James H. Herron. *Iron Age,* Vol. 88, p. 1140-44, 1911. Paper read before the Metal Trades Superintendents and Foremen's Club of Cleveland.

Traitements Thermiques et Mécaniques des métaux à l'atelier. By F. Robin and P. Gartner. *Revue des Mécanique,* Nov. 30, 1911 (serial). Abstracts in Foreign Review of American Society of Mechanical Engineers, Feb. 1912, p. 303-06; July, 1912, p. 1112.

New Process for Chilling and Hardening Cast Iron. By Thomas D.

Digitized by Google

West. American Society of Mechanical Engineers *Journal,* June, 1912, p. 837, 862.

Analysis and Heat Treatment of Low Carbon and Alloy Steels. By Douglas T. Hamilton. *Machinery,* New York, Vol. 18, p. 955-8, 1912. Practice followed by the Frost Gear & Machine Company.

Steel and Its Heat Treatment. *Iron Age,* Vol. 89, p. 1150-51, 1912. From paper read by Robert R. Abbott before the Cleveland Engineering Society. Discusses change in physical properties due to variations in alloys.

Materials Used in Motor Cars. By J. Coapman. *American Machinist,* Vol. 34, pt. 1, p. 736-39, 1911. Describes the heat treatment given the steel.

Automobile Materials. By J. Coapman. *Horseless Age,* Vol. 25, p. 462-64, 1910. Specifications for heat treatment.

Traitements Thermiques des Aciers Spéciaux. By L. Guillet. *Revue de Metallurgie,* Vol. 7, p. 489-95, 1910.

Benefits Derived by Heat Treating Steels. By Thomas J. Fay. *Automobile,* Vol. 19, p. 739, 779, 811, 1908.

Heat Treatment of Carbon Steel. By J. H. Gill. *American Machinist,* Vol. 31, pt. 2, p. 844, 846, 1908.

Heat Treatment of Chrome Vanadium Steel. By A. F. Mitchell. Railway Club of Pittsburgh *Proceedings,* Vol. 12, No. 2, p. 38-54; discussion, p. 54-66, 1912.

Sur le Traitement Thermique et Mécanique des Aciers. By L. Grenet. *Technique Moderne,* Nov. 15, 1912.

Heat Treatment. The treatment of constructional steels for automobile work and the physical qualities obtained thereby. By M. Kowollik. *Internal Combustion Engineering,* Oct. 2, 1912, p. 315-17. Translation from the German.

BOOKS

Lake, E. F.—Composition and Heat Treatment of Steel. Ed. 2. New York: McGraw Company, 1911.

Campbell, Harry H.—Manufacture and Properties of Iron and Steel. Ed. 4. New York: Hill Publishing Company, 1907.

Woodworth, Joseph V.—Hardening, Tempering, Annealing and Forging of Steel. New York: Henley Publishing Company, 1903.

Stoughton, Bradley.—Metallurgy of Iron and Steel. Ed. 2. New York: McGraw-Hill Co., 1911.

Harbord, F. W., and Hall, J. W.—Metallurgy of Steel, Ed. 4, Vol. 1, Chapter 18. London: Griffin, 1911.

Jones, Bernard E.—Hardening and Tempering Steel. A workshop guide to the heat treatment of steels, including high-speed. London-New York: Cassell & Company, 1911.

Brearley, Harry.—Heat Treatment of Tool Steel. London-New York: Longmans, Green & Company, 1911.

Gages, Léon.—Traité de Métallurgie du Fer. Vol. 2. Paris, 1898.

Digitized by Google

Sauveur, Albert.—The Metallography of Iron and Steel. Cambridge, Mass.: Sauveur & Boylston, 1912.

Colvin, Fred H., and Stanley, Fr. A.—American Machinists' Handbook. New York: McGraw-Hill Company, 1909, p. 315.

Bibliography—Structural Modifications of Metals and Their Causes; Heat Treatment. International Association for Testing Materials *Proceedings,* Vol. 2, No. 3, p. 90-97; Vol. 2, No. 6, p. 305-315, 1912.

## PHYSICAL PROPERTIES

Bibliography. Iron and Steel and Their Alloys. Their Mechanical Properties. International Association for Testing Materials *Proceedings,* Vol. 2, No. 3, p. 97, 102; Vol. 2, No. 6, p. 315-23, 1912.

Mayari Steel, Its Properties and Uses. *Iron Age,* Vol. 89, p. 69-72, Jan. 4, 1912. Chrome nickel steel made from Cuban chrome nickel iron ore.

Das Vergüten der Automobil Konstruktionsstähle und ihre die dadurch erzielten physikalischen Eigenschaften. By Director Kowollik. *Motorwagen,* Vol. 14, p. 258-62, 1911. Influence of heat treatment on the properties of nickel and chromium steel.

The Chemical and Mechanical Relations of Iron, Chromium and Carbon. By J. O. Arnold and A. A. Read. Iron and Steel Institute *Journal,* 1911, pt. 1, p. 249-60; discussion, p. 261-68.

The Chemical and Mechanical Relations of Iron, Manganese and Carbon. By J. O. Arnold and A. A. Read. Iron and Steel Institute *Journal,* 1910, pt. 1, p. 169-81; discussion, p. 182-84.

Selection and Treatment of Alloy Steels for Automobiles. By Henry Souther. Franklin Institute *Journal,* Vol. 170, p. 437-50, 1910; *Page's Weekly,* Vol. 18, p. 19-23, 1911. *Revue Industrielle,* Vol. 42, p. 234, 1911.

Alloy Steels for Railroad Use. By Henry Souther. *American Engineer and Railroad Journal,* Vol. 85, p. 95-98, 1911. Abstract of paper read before the Engineering Club and the Altoona Railroad Club. Points out the importance of heat treatment of alloy steels.

Expériences sur la dureté des aciers trempés et particulièrement sur la dureté des aciers cémentés et trempés. By A. Portevin and H. Berjot. *Revue de Métallurgie,* Vol. 7, p. 61-75, 1910.

Special Steels in Theory and Practice. By Walter Giesen. Iron and Steel Institute. Carnegie Scholarship Memoirs, Vol. 1, p. 1-59, 1909. Section 4 discusses the mechanical and physical properties of various special steels.

Alloy Steels for Motor Car Construction. By John A. Matthews. Franklin Institute *Journal,* Vol. 167, p. 379-97, 1909. Tables show typical analyses, treatments and tensile tests of nickel, nickel-vanadium, chrome-nickel and chrome-vanadium steels.

Contribution to the Study of the Special Ternary Steels. By Albert M. Portevin. Iron and Steel Institute. Carnegie Scholarship Memoirs, Vol. 1, p. 230-64, 1909. This research comprises two portions: "The ap-

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plication of shearing tests to the special steels" and "A study of the electrical resistance of the special steels."

Strength and Structure of Alloys. By Walter Rosenhain. Incorporated Institution of Automobile Engineers *Proceedings,* 1906-7, p. 71-92; discussion, p. 93-106.

Quarternary Steels. By Léon Guillet. Iron and Steel Institute *Journal,* 1906, pt. 2, p. 1-141. The author discusses the various kinds of nickel and chromium steels.

Steel Used for Motor Car Construction in France. By Léon Guillet Iron and Steel Institute *Journal,* 1905, pt. 2, p. 166-189; discussion, p. 190-203.

Seventh Report to the Alloys Research Committee, On the Properties of a Series of Iron-Nickel-Manganese Carbon Alloys. By H. C. H. Carpenter, R. A. Hadfield and Percy Longmuir. Institution of Mechanical Engineers. 1905, pts. 1-4, p. 857-959; discussion, p. 959-1041.

Heat Treatment Experiments with Chrome-Vanadium Steel. By H. Riall Sankey and J. Kent Smith. Institution of Mechanical Engineers. 1904, pt. 4, p. 1235-82; discussion, p. 1283-1317.

Influence of Carbon, Phosphorus, Manganese and Sulphur on the Tensile Strength of Open-Hearth Steel. By H. H. Campbell. Iron and Steel Institute *Journal,* 1904, pt. 2, p. 21-62; discussion, p. 63-68.

BOOKS

Campbell, H. H.—Manufacture and Properties of Iron and Steel. Ed. 4. New York: Hill Publishing Company, 1907. Chapter 17—The influence of certain elements on the physical properties of steel.

Grenet, L.—Trempe, recuit, cémentation et conditions d'emploi des Aciers. Paris: Béranger, 1911.

Guillet, Léon.—Les Aciers spéciaux. Paris: Dunod, 1904 and 1905.

Harbord, F. W., and Hall, J. W.—Metallurgy of Steel. Ed. 4, Vol 1. London: Griffin, 1911. Chapter 17—Special steels or steel alloys.

Howe, Henry Marion.—Iron, Steel and Other Alloys. Ed. 2. Cambridge, Mass.: Sauveur, 1906.

Howe, Henry Marion.—Metallurgy of Steel. New York: Scientific Publishing Company, 1890.

Ledebur, A.—Handbuch der Eisenhüttenkunde. Ed. 5. Leipzig: Felix, 1906-1908. Part 1, p. 392-401 contains bibliography of special steels.

Mars, G.—Die Spezialstähle, ihre Geschichte, Eigenschaften, Behandlung und Herstellung. Stuttgart: Enke, 1912.

Martens, A.—Handbuch der Materialienkunde fur den Maschinenbau. Berlin: Springer, 1912. Part 2. Die technisch wichtigen Eigenschaften der Metalle und Liegierungen. By E. Heyn.

Sauveur, Albert.—The Metallography of Iron and Steel. Cambridge, Mass.: Sauveur & Boylston, 1912.

Savoia, Humbert.—Metallography Applied to Siderurgic Products. Translated by R. G. Corbet. London: Spon, 1910.

Stoughton, Bradley.—The Metallurgy of Iron and Steel. Ed. 2. New York: McGraw-Hill Book Company, 1911. Chapter 15. Alloy steels; also p. 514-16, Bibliography.

Digitized by Google

CAST IRON

Chemical Standards for Iron Castings. By John Jermain Porter. American Foundrymen's Association *Transactions,* Vol. 19, p. 35-198 convention (1910), published 1911. Pt. 2 discusses the relationship between the various physical properties and the chemical composition of cast iron. Pt. 5 is a bibliography on the subject of cast iron, its chemical composition and physical properties. Pt. 2 is abstracted in *Foundry,* Vol. 37, p. 141-46, 1910.

Influence of Vanadium Upon the Physical Properties of Cast Irons. By W. H. Hatfield. Iron and Steel Institute *Journal,* 1911, pt. 1, p. 318-26; discussion, p. 327-331.

BOOKS

West, Thomas D.—Metallurgy of Cast Iron. Cleveland, 1897. Pt. 4, Testing physical properties of cast iron.

Hatfield, W. H.—Cast Iron in the Light of Recent Research. London: Griffin, 1912. The influence of silicon, manganese and other elements on cast iron; also the heat treatment of cast iron.

MANGANESE STEEL

Ueber den Einfluss des Mangans auf die Eigenschaften des Flusseisens. By G. Lang. *Metallurgie,* Vol. 8, p. 15, 49, 1911. With bibliography.

Manganese Steel. By J. F Springer. *Cassier's Magazine,* Vol. 39, p. 100-16, 1910.

Manganese Steel. By W. S. Potter. Western Society of Engineers *Journal,* Vol. 14, p. 232-40, 1909. The author discusses physical properties and heat treatment.

Manganese in Its Application to Metallurgy. Some newly discovered properties of iron and manganese. Two papers by Robert Abbott Hadfield. Institution of Civil Engineers, Vol. 93, p. 1-75; discussion, p. 75-126, 1887-1888, pt. 3.

CHROMIUM STEEL

Some Physical Properties of 2 Per Cent. Chromium Steels. By Andrew McWilliam and Ernest J. Barnes. Iron and Steel Institute *Journal,* 1910, pt. 1, p. 246-67; discussion, including a discussion of a paper by Harold Moore on the 2A point in chromium steel, p. 276-286.

Alloys of Iron and Chromium. By R. A. Hadfield, including a report by F. Osmond. Iron and Steel Institute *Journal,* 1892, pt. 2, p. 49-131; discussion, p. 132-175. Bibliography, p. 130-131.

STEEL CASTINGS

Strength of Steel Castings. By E. F. Lake. *Machinery,* Vol. 17, p. 534-36, 1911.

Properties of Nickel Cast Steel. By Edwin F. Cone. *Iron Age,* Vol 90, p. 287-88, 1912.

BOOKS

Carr, W. M.—Open-Hearth Steel Castings. Cleveland: Penton Publishing Company, 1907. Chapter 7. Relation between composition and physical properties.

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### NICKEL STEEL

Der Einfluss von Nickel und Kohlenstoff auf Eisen. By G. Goldberg. *Giesserei Zeitung,* Vol. 6, p. 161, 193, 1909.

Zur Kenntnis der Festigkeitseigenschaften des Nickelstahles. By E. Preüss. *Stahl und Eisen,* Vol. 29, p. 422-25, 1909.

Versuche mit Druckstäben aus Nickelstahl. By F. Bohny. *Stahl und Eisen,* Vol. 31, p. 1287-92, 1911.

### VANADIUM STEEL

Influence of 0.2 Per Cent. Vanadium on Steels of Varying Carbon Content. By Andrew McWilliam and Ernest J. Barnes. Iron and Steel Institute *Journal,* 1911, pt. 1, p. 294-310; discussion, p. 311-17.

Vanadium Alloy. By G. L. Norris. Franklin Institute *Journal,* Vol. 171, p. 561-84, 1911.

Properties of Vanadium Steel. By William E. Snow. *Machinery* (New York), Vol. 17, p. 704, 1911. Tables are given showing the tensile strength and elastic limit under different conditions of chrome nickel, chrome nickel vanadium and chrome vanadium steels.

Vanadium Steel. By William E. Gibbs. *Cassier's Magazine,* Vol. 38, p. 174-181, 1910.

The Use of Vanadium in Metallurgy. By Léon Guillet. Iron and Steel Institute *Journal,* 1905, pt. 2, p. 118-165.

## DISCUSSION OF IRON AND STEEL DIVISION REPORT

HENRY SOUTHER.—This report is made because of the request of the Society in open meeting for more physical results than we had given. You will find in the report refinements rather than extensive additions, for the simple reason that the committee could not do more, did not know how to do more, I may almost say. We want to satisfy the Society in its demands. We have gone just as far as it seems safe to go. Our report is again one of instruction, supplementary information to accompany the specifications. It is not complete; it may not be complete for two or three years. For example, the new tests of hardness are becoming recognized, the Brinell and scleroscope. They will be added to the tension and other tests just as fast as we get information that is worth giving you. Please bear in mind that this is not a standard, but good information that we are preparing for you; that is all your committee feels it is possible to do.

### SPECIFICATION FOR NICKEL STEEL FOR VALVES ELIMINATED

We have eliminated one specification because it has become obsolete—nickel steel for valves. It appears that in the development of the art those steels have practically passed out of use and that for extreme conditions the so-called high-speed tool steel or tungsten steel has come into use exclusively, and that for ordinary use each engineer has his own particular simple steel that he considers best. That is about the only marked change that has been made, I think.

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### CHEMICAL AND PHYSICAL SPECIFICATIONS NOT TO BE COMBINED

The reading matter under the heading "Notes and Instructions" has been altered in detail only as stated before. We again point out the absolute necessity of not attempting to combine physical and chemical results in the purchase of steel. What I mean to say is this: if you are buying steel on physical specifications, do it that way and let the steel-maker modify the chemical composition to meet the physical requirements. If you are buying on chemical composition, give the steel-maker some leeway as to physical property. You cannot tie him hand-and-foot and then expect results. The committee goes back to that every time, both producer and consumer members.

There is only one further remark that I want to make, and that is that the producer turned up at our last committee meeting in larger proportion than the consumer. For that I am very sorry. We must have the user present. Else the committee work is not complete.

G. F. FULLER.—I would like to ask if the physical characteristics which as stated should be obtained with proper heat treatment were obtained by actual experiment; that is, if actual tests were made to obtain the figures given in the table of physical characteristics of the different steels.

HENRY SOUTHER.—Yes, the figures given there represent the beginning of an investigation of what is possible; concrete cases of what has been done by some of our committee members or the companies that they represent.

G. F. FULLER.—I think there will necessarily have to be a great deal more work done in pulling tests than the results of these tables show. In the case of some grades of steel that we are handling, the table shows figures which I would not feel satisfied with in sending goods out. For instance, the 10-45 steel, treatment C, drawn to 1,100° F., shows an elastic limit of 76,500, with reduction of area of 43.5 per cent. I would insist that it show better than 50 per cent. reduction of area, with that elastic limit, in our ordinary practice. I consider 43.5 as being somewhat dangerous in crankshafts.

Referring to the last test of 31-40 steel, M—1,200° F., I think that if one averaged a great many tests he would have difficulty in showing a reduction of area of 65 per cent. with 100,000 lbs. elastic limit.

### YIELD POINT AND ELASTIC LIMIT

I would like to refer to one other point in connection with this report. We have had trouble recently in the interpretation of yield point in relation to elastic limit. We find that in tests made by some of our customers the yield point varies considerably from a diagrammatic representation of elastic limit on the Olsen testing machine. The discrepancies which naturally result from the different interpretation of the terms should be cleared up.

HENRY SOUTHER.—The comments of Mr. Fuller are very pertinent. It should be stated, perhaps, somewhere in print—I thought it was—that the data given here are the beginning only of data to be accumulated and that the intent is to connect tension tests and hardness tests; that

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is to say, "31-40 treatment M-1,200° F., 100,000 pounds elastic limit," is not to show what can be done every day in the week; it is not a specification. It is a bit of data which connects the elastic limit in one case with the Brinell hardness and the Shore hardness. After we get a large number of figures of that character from our members, which we are trying to do, we will be able to draw from them specifications which are worth while. These are not specifications.

Regarding the confusion of yield point and elastic limit, the committee spent—well, I thought it was altogether too much time—over that one matter. It has been since I have known anything about steel a subject for discussion in engineering societies. Briefly, with soft steel, let us say up to 100,000 elastic limit, if you please, the yield point may be determined by a sudden drop of the beam, because the steel weakens instantly. I am using only approximate figures now—and there is not much difficulty in arriving at what is a practical failing point for the steel. I am not discussing whether it is the real elastic limit or what it is, but it is something that indicates to the trained eye that the steel's back is broken. That is about all you want to know.

In the case of the stronger steels, of say 150,000 elastic limit, the beam does drop suddenly and there is no indication to the trained eye that that steel's back is broken. We must go to extremes to find out when the steel begins to weaken. We do it by means of an extensometer of one form or another; any reasonably good extensometer will do the work. The curve goes up with a uniform progression until at some point it changes its rate of curve. That is usually taken as an indication of the elastic limit. Maybe another point is in the elastic limit theoretically. That makes no difference to me as an engineer selecting steel for an automobile. I am not splitting any hairs. I am not measuring bricks with a micrometer. I am trying to find out what is safe and what is not safe. If there is a sudden break in the curve of the extensometer, I know that the elastic limit is somewhere within reasonable distance of that point. That is as far as your committee cared to go. It has expressed its view in this report as follows: "The yield point is specified rather than the elastic limit. The yield point is measured by the drop of the testing machine beam and may safely be relied upon for material having a yield point not in excess of 100,000 pounds per square inch. With material having a yield point in excess of 100,000 pounds per square inch, the true elastic limit should be obtained by means of an extensometer."

It is impossible to state in one paragraph all there is that ought to be stated about elastic limit and yield point. The minute we start in upon that subject and attempt to cover it beyond argument, we go right back to a useless discussion of what it is. We have to leave something to the engineer. I do not know that there is anything more to be said on the subject.

G. F. FULLER.—I do not know whether the engineer I had in mind had been considering this point; I would judge not. He had an electric apparatus which he used as an extensometer to get the yield point. As he probably makes only one test where we make one thousand, he can spend

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a lot of time on it and get down to a point where he removes the load and measures the stretch. He considered the yield point established where he found .001" increase between punch marks. As that was in a metal which showed about 75,000 elastic limit and his yield point showed when loaded to about 5,000 less than ours, bringing it below the specifications, we got into hot water. The only reasonable way, it seemed to me, it could be handled was by the use of the extensometer in testing the lower elastic limit metals. If one wants to measure the stretch with load removed that does not appear by the ordinary method, that is by the diagrammatic registration of the drop of the beam, it seems that we might get together on some minimum stretch that would compare with what the drop of the beam shows.

HENRY SOUTHER.—That is just the thing that we discussed, and we were afraid to try. There is no point that we can lay down that some engineer like the man you are talking about will not squirm around and create friction. The only thing to do in a case like that is to call for help.

G. F. FULLER.—That is what we did.

HENRY SOUTHER.—Get in somebody and say "Is this reasonable? What are you going to do with a man like this? What can you do?" There are bound to be exceptions to our rules. The type of man that you mentioned is an exception. As nearly as we can find out from the experience of the different committeemen, those cases are very rare. We have to go along as best we can with that sort of work. We sometimes meet a man who splits thousandths in phosphorus, whereas our limit of error is five-thousandths. This cannot be helped. There is much horse-sense that has to be applied in the work the Society is doing. I have seen other engineering societies wasting half a morning on a point that is not worth talking about, and I hope we will not. When you get into trouble with laboratory results, you take it to a third party and usually settle it promptly. Take it to the Bureau of Standards, if you like.

B. B. BACHMAN.—Referring to the table of physical properties of the 10-45 steel, there is no 10-45 steel listed in the Notes and Instructions. Then, of two heat treatments, both type C, 1,100° F., one shows 71,000 elastic limit with a reduction of 57.3, and the other 76,500 elastic limit, with a reduction of 43.5. Is there not some error here?

HENRY SOUTHER.—Those are two results obtained in two test-specimens of the same thing. That is one illustration of the variation possible under ordinary treatment. Now, as to 10-45, that is a case where the user of steel was not satisfied with either .40 carbon or .50 carbon, which would have read 10-40 or 10-50; he made a selection between, 10-45.

B. B. BACHMAN.—Then that steel would run from .40 to .50 carbon?

HENRY SOUTHER.—Exactly.

REPORT ACCEPTED.

C. B. WHITTELSEY.—I move that the report be submitted to the Society for acceptance.

W. P. KENNEDY.—I second the motion.

The motion was put to a vote and carried.

(Chairman Souther resumed the chair).

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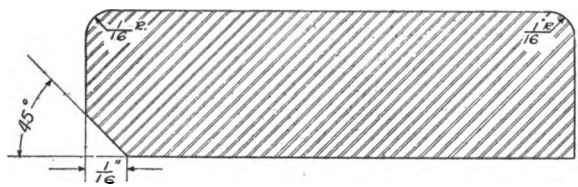
# FOURTH REPORT OF COMMERCIAL CAR WHEELS DIVISION

(Formerly Wheel Dimensions and Fastenings for Tires Division.)

## S. A. E. STANDARD MOTOR TRUCK WHEEL

### EDGES OF PERMANENT METAL FELLOE BAND

We recommend that the permanent metal felloe band be rounded on the two outside edges with radius not to exceed 1-16", and that one inside edge of the band have an angle of about 45 degrees, extending about 1-16" from the edge as shown in the following sketch:




### TOLERANCE IN WIDTH OF PERMANENT METAL FELLOE BAND

We further recommend that the previous recommendation as to tolerance in width of permanent metal felloe band be modified to read as follows:

| | Plus | Minus |
|---|---|---|
| Tolerance in width | 1-64" | 1-64" |

And, in consequence of the last mentioned above recommendation, that the previous recommendation as to trueness of band when placed on surface plate be modified to read as follows:

> Either side of the band when laid on a surface plate must not clear more than 1-64" at any point.

### TOLERANCE IN CIRCUMFERENCE OF PERMANENT METAL FELLOE BAND

In June, 1911, the Division voted that the tolerance in circumference should be:

| | Plus | Minus |
|---|---|---|
| Before application to wheel | 1-16" | 0 |
| After application to wheel | 1-8" | 0 |

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In February, 1912, the Division, in view of the then more extensive manufacture of rigid-base tires, recommended that the circumferential tolerance should be:

| | Plus | Minus |
|---|---|---|
| Before application to wheel | 1-32″ | 1-32″ |
| After application to wheel | 1-16″ | 1-32″ |

Both of these recommendations were accepted by the Society, the latter, of course, superseding the former.

In this connection the point has been made by wheel manufacturers that if the 1-32″ plus tolerance be taken up in the manufacture of the band, the wheel manufacturer has left to him only one-half or 1-32″ of his 1-16″ plus tolerance in the application of the band to the wheel.

The first view of the Committee at its meeting of November 13, 1912, was that no change in circumferential tolerance should be recommended until a greater demand for such change should be evident. After a long discussion, however, upon motion, duly seconded, it was

Voted that the last mentioned above tolerance in circumference of permanent metal felloe band should be modified to read:

| | Plus | Minus |
|---|---|---|
| Before application to wheel | 0 | 1-16″ |
| After application to wheel | 1-16″ | 1-32″ |

## MEASURING CIRCUMFERENCE OF BANDS

In measuring circumference of the band, if there is no allowance on the tapeline itself, a correction amounting to three times the thickness of the tapeline should be made.

Respectfully submitted.

## *COMMERCIAL CAR WHEELS DIVISION*

William P. Kennedy, *Chairman*

| | |
|---|---|
| H. W. Alden | Jacques Morat |
| Joseph A. Anglada | A. J. Scaife |
| H. D. Church | Charles L. Schwarz |
| C. B. Hayes | A. J. Slade |
| A. M. Laycock | E. R. Whitney |

Charles B. Whittelsey

*Following is given a statement summarizing the recommendations made in all (including the above, the fourth) the reports of the Commercial Car Wheels Division; in other words, a complete statement of the matter contained in the four reports accepted by the Society.*

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## WHEEL DIMENSIONS FOR SOLID TIRES

*Demountable and Non-demountable Rims*

*SINGLE TIRES*

Width of felloe and band.. ¾ inch less than sectional size of tire.
Thickness of steel band.... ¼ inch up to 4½ inch tire; ⅜ inch on 4½ inch and larger tires.

*DUAL TIRES*

Width of felloe and band... Twice the sectional size of tire.
Thickness of steel band.... ⅜ inch for all sizes of tire.

*SINGLE AND DUAL TIRES*

| Sectional size of tire..... | 2 | 2½ | 3 | 3½ | 4 |
|---|---|---|---|---|---|
| Minimum felloe thickness | 1¼ | 1¼ | 1½ | 1½ | 1¾ |

| Sectional size of tire..... | 4½ | 5 | 5½ | 6 | 6½ and over |
|---|---|---|---|---|---|
| Minimum felloe thickness | 1¾ | 2 | 2 | 2 | 2⅛ |

## WHEEL DIAMETER OVER STEEL BAND

*Single and Dual Tires*

| Nom. outer diam. of tires ..... | 30 | 32 | 34 | 36 | 38 | 40 | 42 |
|---|---|---|---|---|---|---|---|
| Wheel diam. over steel band..... | 24 | 26 | 28 | 30 | 32 | 34 | 36 |
| Exact circumf. over steel band; neglecting tolerance | 75 25/64 | 81 11/16 | 87 31/32 | 94 1/4 | 100 17/32 | 106 13/16 | 113 3/32 |

ALLOWABLE DEVIATION FROM PRECISION IN FELLOE BANDS

| | Plus | Minus |
|---|---|---|
| Tolerance in circumf. of band before application | 0 | 1-16″ |
| Tolerance in circumf. of band after application | 1-16″ | 1-32″ |
| Tolerance in width of band..... | 1-64″ | 1-64″ |
| Tolerance in thickness of band..... | 0.006″ | 0.006″ |
| Tolerance in radius of band after application.... | 1-16″ | 1-16″ |

Circumferential deviation from precise figure must be uniform across entire width of band.

Radial deviations must not occur at diametrically opposite points, and there must be no flat spots or kinks in band on finished wheel. Either side of band when laid on a surface plate must not clear more than 1-64″ at any point.

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BOLT EQUIPMENT FOR SIDE FLANGES

*All bolts to be ½ inch diameter*

| Outside diam. tire | Diam. bolt hole circle | Number of bolts | Outside diam. tire | Diam. bolt hole circle | Number of bolts |
|---|---|---|---|---|---|
| 26..... | 18½ | 6, 9 or 18 | 42..... | 34½ | 10, 15 or 30 |
| 28..... | 20½ | do. | 44..... | 36½ | 12, 18 or 36 |
| 30..... | 22½ | do. | 46..... | 38½ | do. |
| 32..... | 24½ | 8, 12 or 24 | 48..... | 40½ | do. |
| 34..... | 26½ | do. | 50..... | 42½ | 14, 21 or 42 |
| 36..... | 28½ | do. | 52..... | 44½ | do. |
| 38..... | 30½ | 10, 15 or 30 | 54..... | 46½ | do. |
| 40..... | 32½ | do. | | | |

EDGES OF FELLOE BAND

Band to be rounded on the two outside edges with radius not to exceed 1-16", and one inside edge to have an angle of about 45 degrees, extending about 1-16" from the edge.

MEASURING CIRCUMFERENCE OF BAND

In measuring circumference of band, if there is not an allowance on the tapeline itself, a correction amounting to three times the thickness of the tapeline should be made.

NOTE.—*All of the foregoing summary, so far as pertinent, applies to metal wheels.*

## DISCUSSION

WILLIAM P. KENNEDY.—Mr. Chairman, we are presenting again for acceptance at this meeting the report which we offered at the Winter Meeting. Due to objections presented against the accuracy which we endeavored by the tolerance recommended to bring about in the manufacture of felloe bands, this report was referred back to committee at the last meeting of the Society. It is the fourth report of the Commercial Car Wheels Division. The tolerances recommended by the committee for standard practice are the result of pressure brought to bear by manufacturers of rigid-base tires, they being interested in bringing about more accurate manufacture of wheels than has been the case heretofore. They are very insistent that the practice recommended is necessary. At the last meeting objections were presented on the part of manufacturers who are not interested in rigid-base tires, claiming that the accuracy represented in the practice recommended would cause increased and unnecessary expense. That is the reason the report was not accepted at the last meeting.

CHAIRMAN SOUTHER.—I understand that a tolerance one sixty-fourth inch plus or minus in width of permanent metal folloe band, was considered too close.

WILLIAM P. KENNEDY.—By some tire manufacturers not interested in rigid-base tires.

CHAIRMAN SOUTHER.—Has your committee reconsidered that and recommended the same tolerance as before, Mr. Kennedy?

WILLIAM P. KENNEDY.—Yes.

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CHAIRMAN SOUTHER.—The matter is before us very clearly. The recommendation of the committee is that one sixty-fourth inch plus or minus in width of permanent metal felloe band, is not too close a tolerance. Have you anything further to say, Mr. Kennedy?

WILLIAM P. KENNEDY.—Nothing except to point out, as we pointed out at the Winter Meeting, that wheel bands made in accordance with the practice recommended in our report, are being manufactured and can be procured on the market at the present time without increased cost.

E. R. HALL.—Mr. Chairman, may I ask whether Mr. Kennedy finds on the market any of these bands which come within the tolerances and are not machined on the edges?

WILLIAM P. KENNEDY.—As I understand it, the machining process is a very slight one. It is done without much expense and is necessary in only a very small proportion of the bands that come through from the mill.

E. R. HALL.—That is, a large proportion of the bands will be really within the tolerance specified?

WILLIAM P. KENNEDY.—Yes, the machining process is so very slight and so very infrequent that the manufacturers who are making the bands having the tolerances specified here, do not feel warranted in making any extra charge.

W. L. BURGESS.—Do I understand you correctly to say, Mr. Kennedy, that the manufacturers who are making these bands with this tolerance and doing machine work, do not charge any more than for the bands on which they do not put machine work?

WILLIAM P. KENNEDY.—They claim that the stock comes to them in such form as to render machine work unnecessary in a large majority of the bands, and that the amount of machine work they have to do is so slight that they are not warranted in making extra charge.

W. L. BURGESS.—Is that just a tolerance or is it rounding the edge that you are speaking of?

WILLIAM P. KENNEDY.—Both the tolerance and the rounding of the edge of the band.

CHAIRMAN SOUTHER.—I understand that Mr. Kennedy refers to all of the machining necessary, whether it be fillets or turnings, to get the accuracy specified. Is that right?

WILLIAM P. KENNEDY.—Yes.

CHAIRMAN SOUTHER.—In other words, the band has to be set up in the machine to get the fillets, and while they are cutting the fillets or the rounded corners, they get all the rest with equal ease?

WILLIAM P. KENNEDY.—Yes. Moreover, the stock comes through with a round edge, approaching very closely that shown in the illustration in the report.

CHAIRMAN SOUTHER.—Some of it does not need machining on the round edge?

WILLIAM P. KENNEDY.—Not always.

CHAIRMAN SOUTHER.—Some of it does?

WILLIAM P. KENNEDY.—Yes.

CHAIRMAN SOUTHER.—Is that clear, Mr. Burgess?

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W. L. BURGESS.—It is clear to me that if you put the band in a boring mill to make it as shown in the illustration, it is certainly going to cost enough money to make a charge for it. We find it costs considerable to do that work.

CHAIRMAN SOUTHER.—Mr. Burgess, to get down to something that is concrete, what would be the increase in cost from your standpoint?

W. L. BURGESS.—At least fifteen cents a band.

CHAIRMAN SOUTHER.—What is the total cost of a band?

W. L. BURGESS.—For the dual band, possibly a dollar and a half, average price.

CHAIRMAN SOUTHER.—Then you would say 10 per cent.?

W. L. BURGESS.—Yes.

C. B. WHITTELSEY.—I know it to be a fact that two, if not three, companies are delivering bands made to the tolerance specified in the report under discussion, without any cost in addition to that of bands they produced before these tolerances were recommended, or before we considered the subject for this report. Some of the prominent manufacturers of solid-base tires require bands with turned corners. We are getting these bands and I know of other large companies that are getting them today under the same circumstances.

CHAIRMAN SOUTHER.—In other words the tolerance imposed by this report would not increase the cost over that of the old practice; is this right?

C. B. WHITTELSEY.—Yes, sir. Two manufacturers, if not three, have developed the manufacture of bands so that they can be turned out at exactly the same cost.

J. H. WAGENHORST.—Mr. Chairman, I would say that Mr. Whittelsey's statements are correct from my observations, and also from reports I have heard from the rim manufacturers.

E. R. WHITNEY.—Our purchasing department specified the closer limits and we are getting wheels right up to date, in accordance with this report, without any additional expense. As a member of the Commercial Car Wheels Division I can say that this report was absolutely unanimous; there was not a dissenting vote in the committee, after pretty full investigation.

C. B. WHITTELSEY.—When this report was referred back to the committee, we went into the subject in detail and checked ourselves up on it. I can verify it from the purchasing point of view myself.

REPORT APPROVED

HOWARD MARMON.—In view of the fact that the specifications as outlined in this report are virtually a standard now in the open market, I move that the fourth report of the Commercial Car Wheels Division be approved for submission to the Society for acceptance.

C. B. WHITTELSEY.—I second the motion.

(The motion was put to a vote and carried).

On motion, the meeting adjourned.

COKER F. CLARKSON,
*Secretary.*

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# PRESIDENTIAL ADDRESS

Gentlemen, the midsummer meeting of 1913 of the Society of Automobile Engineers will please come to order. Your president is glad to report that the Society is in a good financial condition and that the membership is showing a healthy increase, as reports that follow will show. One of the main works of the Society, the establishment of recommended practices and standards, has reached a point where the standards and practices carry great weight throughout the entire motor car industry. Development is necessarily slow, but a great deal of discussion takes place in working out what is done and probably this discussion is as valuable as the actual standards themselves, as indicating the pitfalls that should be avoided. As the activities and the momentum of the Society increase, the need for a greater and broader field of standards work becomes apparent. A plan is on foot by which it is hoped to gather enough funds to properly finance a very comprehensive standards plant.

The Sections of the Society during the past few months have been showing an increased amount of activity and it is well that they should. It is hoped that they will become even more active. The meetings of the Sections keep our members up to date in a way that is impossible from the semi-annual meetings we have of the national Society. What takes place in the Section meetings is, as you know, published in the S. A. E. Bulletin, which has become a healthy monthly magazine.

HOWARD MARMON.

# ADDRESS BY T. B. BROWNE, PRESIDENT OF THE INSTITUTION OF AUTOMOBILE ENGINEERS

## Announcement of President Marmon as First Honorary Member of I. A. E.

President T. B. Browne.—Mr. President and Gentlemen: I feel it a very great honor to be allowed to address you on this very important occasion. We wish as an institution to express our very great gratitude and thanks for all the hospitality we have received from the Society of Automobile Engineers as our hosts, and we feel that we cannot with mere words express our thanks and the feeling of gratitude that we have for your great kindness to us. We have been very greatly touched by your many graceful courtesies and attentions to us in our visit to this country. We have therefore decided that we should very much like to ask your president, Mr. Howard Marmon, to become our first honorary member. (Applause.)

I should like to say that up to the present we have not made an honorary member at all in our Institution and we regard this ourselves as the greatest honor we can bestow. We are not in a position legally to arrange this while we are here, as there are certain formalities to be gone through, according to the articles of our Institution, before this can be

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carried out; but we are quite sure that when we return home and inform our members of the popularity of your distinguished president and how extremely kind and gracious you have been to us, they will applaud what we are doing now. In doing this, we feel that Hr. Howard Marmon is in every way worthy of the honor we are proposing to bestow on him, both from his distinguished position in the profession to which we are all devoted, and also by reason of his scientific and engineering attainments which have resulted in the success of the Marmon car in this country. I am therefore quite sure that soon after we get back to England we will send out the formal notice of his election as our first honorary member. (Applause.)

PRESIDENT MARMON.—Gentlemen, this is a very graceful thing that the Institution of Automobile Engineers has done. I am sure that we all understand that the courtesy is one that is extended to the members of the Society through their president rather than to the president himself.

PRESIDENT BROWNE.—May I make another announcement before you proceed with the ordinary business of the session? There is another gentleman here who has been extremely kind to us and looked after us in a most interesting way. He is a gentleman who does not seem to ever want any food or sleep; I think you know whom I mean. I refer to our great big friend, or chum, Mr. Coker Clarkson. (Applause.) He has been most energetic in looking after us and we therefore wish to show our appreciation of his efforts in taking care of our comfort and pleasure, by presenting him with this little token of our regard, and I trust that he will accept it in the same spirit in which it is given.

(Presents loving cup to Secretary Clarkson.)

SECRETARY CLARKSON.—Gentlemen, it is most inappropriate to interrupt our technical work in this way. (Laughter.) I can only say that I thank the Institution of Automobile Engineers with all my heart. (Applause.)

## TREASURER'S REPORT

The treasurer's report was submitted, and on motion, duly seconded, accepted and ordered placed on file.

## REPORT OF TELLERS OF ELECTION OF MEMBERS

The detailed report of the tellers of election of members was submitted, and the election of members of various grades, since the last meeting of the Society, declared by the President as follows:

| | |
|---|---|
| Members | 72 |
| Associates | 92 |
| Juniors | 6 |
| Affiliate members | 4* |

*Number of Affiliate Member Representatives Appointed: Seven.

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# FOURTH REPORT OF IRON AND STEEL DIVISION*

## DISCUSSION

HENRY SOUTHER.—Mr. President and members of the Society and of the Institution of Automobile Engineers: At the strenuous request of the open meeting last winter the Iron and Steel Division has attempted to amplify its report in the matter of physical properties of S. A. E. Steels, particularly as to hardness tests coupled with strength and toughness tests. The report, which has been printed in full and been before you for some time, is too long and contains too many figures to attempt to read it. I will call your attention to only the salient features and then request criticism.

The first thing we wish to bear down upon very hard is that the chemical specifications are one thing and may be used in the purchase of steel. The information therein goes to the purchasing agent; what he must have in order to go to the steel companies and buy without the danger of asking for misfits. It has been the experience of all steel workers, possibly, to have engineers ask for things that could not be produced. Now if the chemical compositions only are used, there is no question but that the steel works can produce the goods if they are in the business. But the moment you couple with the chemical specification a great many of the physical properties given, you may hand to the steel works a problem that cannot be solved. In other words, physical characteristics demanded may conflict with the chemical composition and make the matter an impossible one. So in using S. A. E. steel specifications we ask that either one or the other systems be used for the purchase of material but not both. For example, some parts are purchased in the heat treated condition, properly annealed, for a given purpose. You know what the elastic limit must be, what the strength must be, in order to drive your car, in the propeller-shaft or rear axle shaft, perhaps. You name a definite elastic limit and corresponding toughness. That is all right, because you are not going to reheat the steel, forge it or anneal it, case-harden it or anything else; the shaft will be put to work just as it is purchased. There is no need for chemical specifications in connection with such a transaction, except to tell whether the steel is to be a plain nickel or a plain carbon or perhaps a nickel chromium. Giving the exact composition and also elastic limit and toughness, is not a good procedure. It leads to trouble and no good.

In the physical characteristics tables will be found for the first time an attempt to couple the Brinell hardness test and the Shore hardness or scleroscope test with elastic limit and elongation. The data from this form of test are slowly accumulating, slowly becoming available in the art. Let me indicate why. A shaft purchased from a shaft-maker, prac-

*For text of report see page 7.



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tically finished for use, should be tested in order to find out whether it is as strong as it ought to be. A tension test will destroy it, if one be taken for a sample; and a torsion test would destroy it also. In the Brinell test or possibly in the Shore scleroscope test is found one that can be applied to every individual shaft, if you wish, without destroying it. So just as soon as our knowledge is sufficient, this test is likely to become one of great importance in the inspection of purchased parts already treated and ready for use.

The same thing applies to very hard material like ball bearings or to semi-hard material like a spring. The Brinell test indicates the elastic limit of an individual spring leaf. It is quite possble to pick out of an assembled spring a soft leaf by means of the Brinell test.

Mr. G. F. Fuller has called attention to the fact that there are discrepancies in the tables of physical characteristics. The discrepancies are quite natural. The tests have been accumulated by the committee from many sources. They have been conducted under more or less unlike conditions. The observations have, perhaps, been made in an unlike manner. He fears, and quite properly, that some of you will seize upon these figures as being typical of what is possible in the art and ask the steel works people to duplicate the figures. In some cases that is quite possible. In other cases it may not be. The reason for the submission of these figures is that they give us our first data connecting the elastic limit and hardness tests. They are not specifications. We will insert in the report a paragraph which will warn the users of the report against this.

### VALVE MATERIAL

In the chemical specifications submitted in our third report (January, 1912) have appeared specifications for valve materials. These have been eliminated from the present report. In the early days we were forced into the use of nickel steel, either 28 per cent., 99 per cent., or something of that kind, for valves. The art has changed in such manner that those steels are hardly in use now. The specifications have not been removed and you will find in place reference to what would seem to be the ultimate valve material, high-speed tungsten tool steel, containing 18 per cent., more or less, of tungsten, and half that amount of chromium. We have not attempted to give the actual analysis of this steel, because we feel the time is not yet ripe from a practical standpoint.

There is one more item that I will take time to mention. It is this: You will find that we have substituted in some of the specifications the words "yield point" for the words "elastic limit," and have pointed out the fact that in the case of relatively soft steel, up to 100,000 pounds elastic limit, the yield point is determined by the drop of the beam of the testing machine. That drop indicates to the trained observer simply that the steel or the specimen has reached a point where it weakens, where—I know of no better way to express it—the back of the steel is broken; and that beyond that point the steel is useless so far as structural purpose is concerned. For the harder steels there is no drop of the beam and the extensometer, a refined instrument, must be resorted to.

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We have not attempted to define elastic limit. That has been attempted, so far as my knowledge is concerned, for the last thirty years, and is still a very fruitful topic for discussion. We are assuming commercial things here and not theoretical things; consequently we have left the matter in the condition where any trained observer may tell the steel furnishers that his steel is not up to the elastic limit or yield point or that it is. We are splitting no hairs on this matter but leaving it in a purely commercial condition.

PRESIDENT MARMON.—Mr. Souther has made quite clear what the modification of the old report is. Are there any remarks or queries concerning it? This report was approved by the Standards Committee at a meeting held last night and if accepted by this meeting becomes recommended practice of the Society.

G. F. FULLER.—As Mr. Souther has indicated, I have taken up the subject somewhat with reference to the physical properties and the recommended practices as they would stand if this report were accepted. The matter of physical properties is, of course, a most important one. That being the fact, it seems to me the subject should be approached with considerable circumspection. There is no doubt that your committee has approached it in that manner. Their preliminary work of recommendation of analyses and heat treatments of course led up to the final physical properties. I presume that the committee has had some difficulty in getting together a table that fairly illustrates the physical characteristics of the metals. As Mr. Souther has stated, a great many of the tests were made under unlike conditions, and, quite evidently from the figures derived, unlike conditions of metal that was supposed to be the same. I understand perfectly that this matter is one of recommended practice only and hardly that in reference to the physical properties. But as our president stated in his opening remarks, the recommended practice of the Society carries great weight. The company with which I am connected has felt this to be so. While a great many of the published figures referring to the chemical analysis and the heat treatment of steels, were supposedly recommended practice only, they have assumed in our relations with the trade and engineers the form of specifications. Engineers have specified to us physical properties desired, and demanded chemical analyses of the steel from which these physical properties were to be obtained and the heat traeatment to which the steel was to be subjected to get them. I understand perfectly that the Society cannot regulate that; that there will always be an over-importance attached to recommendations. But because of that fact it seems to me that we should give added care to the preparation of these figures.

In the opening paragraph of this report I find that the statement is made, referring to physical characteristics, that they are added solely for the information of the user of the steels and for the guidance of the purchaser. Now, if that is true, which of course it is, there should be given figures that would be a proper guide. I do not wish to criticise the figures unduly, because there is no question but that they have been gathered under conditions that almost prohibit their being entirely consistent. If

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the committee did not get any better response from the most of the people whom they asked to submit figures, than they did from me, I can readily see why that is so. But I do feel that the figures will be used, and that therefore, they ought not to be accepted until they are such as will form a guide at least. There are a number of discrepancies. I would like to call your attention to a few that I noticed as I scanned the figures more or less superficially. In the case of the 10-30, of the fourth group, the 10 referring to the grade of steel, being a simple carbon steel, the 30 referring to the carbon content, I note that with treatment C, drawn to 500° F., the figures given for guidance are 85,000 elastic limit and 17 per cent. reduction of area. In the fourth line of that same group occurs the same condition, 10 grade, 30 carbon, C treatment, 500° F., 104,000 elastic limit and 54 per cent. reduction of area. I cannot see the guidance. If you were considering that steel for some specific use, the 17 per cent. reduction of area would indicate there is something all wrong the matter with it. It is not fit to use. Going down further, the 10-45 is a class that requires a great deal of preparation of figures. It is a grade of steel which is used very largely. You will not find that exact specification in the chemical specifications, but it would be included between the 10-40 and the 10-50. Taking 10 grade, 45 carbon, C treatment, 1,100° F., we get 71,000 elastic limit, 57.3 per cent. reduction. That same treatment two lines below gives 76,500 and 43 per cent. reduction. These are not so pronouncedly different as those I first quoted, but are far enough apart that if any engineer or purchasing agent should allow that reduction of 43 per cent. to pass inspection he would be likely to get into trouble. Our practice is to not allow an elastic limit of 76,500 (in fact an elastic limit in that metal will be about 80,000) to pass a coupon that showed a reduction any less than 50 per cent.

Further on there is an even more pronounced discrepancy. In the nickel chromium steel, in the 32 grade, 40 carbon, treatment M, the first line gives an annealing or drawing temper of 400° F. That should result in 230,000 elastic limit and 35 per cent. reduction. In the next line, of the same grade, drawn to 100° higher, the elastic limit drops to 186,000, which is probably pretty fairly proportioned. But instead of increasing the reduction drops to 4 per cent. There was a flaw of some kind in that specimen, for the reduction should have increased with increase of drawing temperature.

I could go through this further, but will turn to one more case only, 61 grade, 50 carbon. The treatment is T. Drawing to 800° F., you get 220,000 elastic limit and 30 per cent. reduction of area. That same treatment on the next line, grade 61, carbon 50, treatment T., 800 drawing temperature, gives 200,000 elastic limit and 50 reduction. Well, now, 30 or 50, by which are you to be guided? You are going to be guided into error if you use one or the other.

It would seem that the tables should be scanned pretty thoroughly, because they are going to be used, if to no further extent than the report recommends, for guidance, and they will guide you wrongly if you pick the wrong figure. The company with which I am connected has many

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thousands of records of tests of nearly all these different grades; in one or two of the higher chromium nickel vanadium we would have to make some, perhaps. But I would state that in order to help out, to get something that when published we can stand back and feel confident of, we would place our entire record of laboratory tests at the service of the committee to get the tables right before submitting them to the public. I cannot quite see the object of publishing these figures and then having to backwater on a lot of them. It seems to me that the physical characteristics of the material are of sufficient importance to want to be as near right as it is humanly possible before publishing.

PRESIDENT MARMON.—Mr. Fuller brings out some points that are very vital. If we do commit ourselves to anything that will not stand the acid test, we lose some of our prestige.

HENRY SOUTHER.—A long time ago I raised a question whether specifications and instructions and notes and other information should ever be printed in the same pamphlet. I rather think I had a good thought at that time. If Mr. Fuller will read the report carefully, he will find that the notes and instructions stand alone, with the next subject appearing as a list of heat treatments, and the next the physical characteristics of the steels. There is an excellent reason why all the freak figures of physical characteristics should appear in print. It is only by judging all kinds of peculiarities of toughness and strength that we can find out whether Brinell hardness and Shore hardness will hold good in all kinds of cases. The list of physical characteristics of carbon steels as printed has no reference whatever to specifications of heat treatment or notes and instructions.

G. F. FULLER.—Mr. President, I considered that feature before I made any remarks in reference to the report. Mr. Souther applied to the discrepancies a stronger term than I dared to, when he called them freaks. It does not appear to me to be the proper place to publish these freaks, because they are going to be used. You can fill the report from cover to cover with recommendations that they *not* be used, but they *will* be used. Former publications of a similar character have been used. It is not at all my idea that physical characteristics of steel should not be published. The "freaks," as incorporated here in relation to Brinell hardness and Shore hardness, I would hardly term freaks. You cannot take, as shown in the tables, two steels of 61 grade, 50 carbon, and treat them alike, starting with the same composition of steel, and handle them right, without making any slip in the treatment or the test, and get a 30 per cent. reduction in one case and a 50 per cent. reduction in the other. My idea in relation to any one of these different steels and its treatment, would be to make not less than one hundred tests at least, each one supposedly an exact duplicate of the other, before publishing a figure as to what that grade, of that carbon, of that treatment, of that drawing temperature, should give as a guidance for ordering. Average a hundred tests and you will get a figure somewhere near what it would be safe to call the physical characteristic of a given metal. To take two that show that there is something wrong in the test and publish them both, does not appear to me to be the logical way of getting at the subject from the standpoint of the guidance of the purchaser.

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HENRY SOUTHER.—I do not want to prolong this discussion too long, but it seems to me there is a way out of this. I appreciate Mr. Fuller's position exactly; I have been there and I know what it means. Some purchaser will come in and say "I want the very highest elastic limit, the very highest reduction of area, the highest elongation that can be found in the book in combination," and expect it to be furnished. Well, he cannot, nor can any one else. Purchasers are going to take that stand now and then by mistake. They always will. You cannot print anything that will stop that sort of man getting busy in that sort of way. There will be a decision; there must be a settlement. What is a better authority for the settlement than is to be found in this Society? For instance, suppose we add to this report, at the head of the tables of physical characteristics of the steels, a very short paragraph to the effect that this is not a list of possibilities, although some of them have happened; it is not for use in connection with the purchase of steel and must not be so used. The purchaser goes to Mr. Fuller and asks for an impossibility or a freak, if you like. Mr. Fuller is perfectly justified in turning to this pamphlet and saying "Gentlemen, we would be very glad to give you anything you like, but you will notice that we cannot give you that which you have asked for, which appears on page so and so of the report. We call your attention also to the paragraph at the top of that list of figures. We are perfectly willing to give you anything under the sun that is possible, but here is your referee. Do not ask me for that. I can furnish you so and so." It seems to me we cannot wait for a hundred tests of every kind of metal. If we do, we will never get anything. I would like nothing better, but we must make a beginning. With the addition of such a paragraph I feel that Mr. Fuller and others in a similar position will be fully guided and protected. It does not seem to me that any reasonable purchaser will demand anything in the face of what has been given so much consideration as this matter has in committee and also in open discussion before this Society.

### REPORT AMENDED ACCEPTED

E. S. FOLJAMBE.—Mr. President, in view of the great amount of work that has been done by the Iron and Steel Division, and also the fact that the companies were called upon to furnish the test data which they evidently had and which they did not furnish at the time they were needed, I move that this report, with the paragraph suggested incorporated, be accepted.

(The motion was seconded.)

PRESIDENT MARMON.—It has been moved and seconded that the fourth report of the Iron and Steel Division, after the insertion of the paragraph referred to, at the head of the tables of physical properties, be accepted. Is there any further discussion?

(The motion was put to a vote and carried.)

## FOURTH REPORT OF BALL AND ROLLER BEARINGS DIVISION HELD OVER

DAVID FERGUSSON.—Mr. Chairman and Gentlemen, I have been waylaid this morning by a deputy from another meeting asking that I, as Chairman of the Ball and Roller Bearings Division, submit to you that our

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fourth report should be held over until the Winter Meeting. We have been trying for three years to get the ball bearing manufacturers to give us some definite statement with regard to limits, but they all want too big a hole to crawl through. Now, after we have settled on something and it has been before the Society for over six months, at the last minute they come in and ask for further time. We do not want to railroad anything through. We want the standards to be right. We want the limits to be such that they can be worked to. I am perfectly willing to let them have a longer time, if they will get together, as they say they will, and give us some reasonable limits that they can work to better than those we have specified in our fourth report. If I am in order, and there are enough members of the committee here, I suggest that we agree to hold our report over until the Winter Meeting.

PRESIDENT MARMON.—I suspect, Mr. Fergusson, that the only way to do, now that the report has got this far, is to present it to the meeting with your comment and ask that it be referred back to committee. That is probably the only regular way to handle it.

DAVID FERGUSSON.—As far as I can understand, we have not a full statement of what changes are wanted in our report. It was desired to get all the manufacturers of ball bearings together and have them agree upon some limits. They want some plus and some minus limit on the outside diameter, whereas our committee report gives them only a minus limit, with no plus tolerance. Then there is some criticism about the eccentricity. They want a bigger limit than two ten-thousandths, in the extremes of the dimensions of the outer and inner rings. They have not settled on the figure they wish us to have here as a limit.

PRESIDENT MARMON.—Is it the sense of the meeting that with this explanation that Mr. Fergusson has made, this report go back to the committee to be reported again at the next general meeting?

F. G. HUGHES.—I so move.

E. T. BIRDSALL.—I would like to move to amend the motion that the report at that time be a final report; otherwise the ball bearings manufacturers will postpone action from year to year.

PRESIDENT MARMON.—Mr. Hughes, is that amendment acceptable?

F. G. HUGHES.—From the viewpoint of the ball bearing manufacturers, Mr. President, that amendment is thoroughly acceptable to all of us.

(The motion was seconded, put to a vote and carried.)

## TRUCK STANDARDS DIVISION REPORT

WILLIAM P. KENNEDY.—Mr. Chairman and gentlemen, we are not prepared at this time to render a formal report covering the work which we are conducting in connection with recommendations for standard practice in the design of trucks. As explained at some of the previous meetings, we are going about this work very cautiously, so that the work may be done well. It calls for a great deal of research. Further than outlining briefly to you the direction in which we are proceeding I have nothing to present.

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In order to cover the field completely we have a committee made up of men who have had varied experience, insuring consideration of all of the elements entering into truck design. These gentlemen, located in different parts of the country, cannot get together often, so we have decided on the formation of a number of subcommittees which we call equipment committees, to make research and digest the material which they collect in the province of each. These special equipment committees are, first, the Wheel Equipment Committee, for the purpose of considering the possibility of reducing the multitude of diameters of truck wheels, and of taking up standardization of such parts of wheel equipment as cannot be conducted by the Commercial Car Wheels Division. The work which this equipment committee will cover is largely influenced by such features of design as the location of brakes, spring seats, etc.

Another subcommittee is considering axle equipment for the purpose of determining whether we can offer recommendations for standard practice covering interrelated points of design and dimensions for a certain series of axle sizes.

Another subcommittee is handling power equipment, perhaps not in relation altogether to the capacity of trucks, but for the purpose of standardizing a good many features which would be of mutual advantage to both the producer and the user.

A fourth subcommittee is handling what we call auxiliary equipment, such apparatus as radiators, recording devices, methods of application, frame width, platform dimensions and other elements which are not essentially parts of the design and which may be classified as auxiliary equipment. We are proceeding very thoroughly and hope to be able at the next meeting of the Society to present a very comprehensive preliminary report on the field which we have in hand.

## FOURTH REPORT OF COMMERCIAL CAR WHEELS DIVISION.*

As chairman of the Commercial Car Wheels Division, I beg to present again the fourth report of the Division, which is unchanged from the form in which it was presented at the last meeting, at which was raised some objection, in view of which it was thought best to hold the report in abeyance six months, so that we could give greater consideration from all points of view to the subjects which the report covers. The report refers principally to dimensions, covering tolerance from precise measurement of felloe bands, forcing more accurate workmanship and manufacture of wood wheels. The limitations we are offering are insisted upon by the manufacturers of rigid-base tires, but are not inconsistent with the present practice of advanced manufacturers. Wheels conforming to the proposed practice are already on the market and can be procured without additional cost.

All the work covered by this Division of the standards committee has been in the four reports it has made, put into one statement printed at the end of its fourth report herewith submitted.

*For text of report, see page 51.

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L. S. BOWERS.—Mr. Chairman, I would like to ask if a date will be fixed on which these new standards will go into effect? My reason for asking that is this: There are considerable quantities of the metal bands that have been made up to the old tolerances, and undoubtedly in the wheelmakers' hands considerable quantities of wheels made up on order to the old tolerances. It would work a considerable hardship to the manufacturers of both the bands and the wheels if these standards should go into effect immediately.

PRESIDENT MARMON.—This standard has been in effect to a considerable extent for some months past, inasmuch as it was discussed and proposed at the midwinter meeting. Since then a large number of the makers have been furnishing to these proposed dimensions.

L. S. BOWERS.—We have at our factory a good many bands that do not conform strictly to the tolerance in width of permanent metal felloe band recommended in this last report.

PRESIDENT MARMON.—The recommended practices go into effect gradually, of course.

REPORT ACCEPTED.

On motion, duly seconded, the fourth report of the Commercial Car Wheel Division was accepted.

# REPORT OF ELECTRICAL EQUIPMENT DIVISION

## ONE- AND TWO-WIRE INSTALLATION

DAVID FERGUSSON.—The Electrical Equipment Division, owing to the transition stage that electric wiring on gasoline automobiles is in at present, feel they cannot go further than to make this statement: "We cannot at this time finally recommend the adoption of the single-wire system, but are very favorably inclined towards it."

PRESIDENT MARMON.—That, of course, is merely a progress report, not up for any action.

J. G. VINCENT.—In connection with the single-wire system, one point I wish to raise for consideration (principally because I think that the single-wire system is not going to work out in every case), and that is the recommendation of a larger Ediswan fixture than is ordinarily obtainable now. We have designed an Ediswan base twice as large as the standard, which we are going to use on our car next year in order to get thorough insulation in every part of the connector, which is not possible with the small standard connector. It might be well for the committee to investigate this larger connector, which I think could be made standard just as well as any if it were recommended by the Society. My chief reason for not being enthusiastic about the single-wire system is that I have yet to see any satisfactory system grounded on either side. It has been my experience that sooner or later you get a ground on the other side. It will not work well with a dual magneto.

PRESIDENT MARMON.—You are referring in that case to a condition

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where the storage battery current is used instead of the magneto in starting?

J. G. VINCENT.—Yes.

F. CONRAD.—In most systems the magneto is grounded on one side. There would be no real advantage in insulating the lighting system circuit, if the ignition system requires a ground.

In regard to the size of the socket, the present socket gives ample insulation with the single-wire system. The underwriters propose to issue a new set of rules about July, in which they will require all circuits below 150 volts to be grounded. The experience with lighting and power circuits has been that the reliability and possibility of finding trouble are greater with the grounded system; I think this would apply equally well to the automobile system, which is more in the class of electric railway systems, where there is a large amount of metal which can be used for the return line, which gives increased possibilities for insulation of the outgoing circuit.

## INSULATION REQUIREMENTS

There is at present no insulation test value that can be applied to the electrical apparatus used on gasoline automobiles. Although a subcommittee was appointed to report on this, they did not have time to make a formal report for submission to the Standards Committee. The American Institute of Electrical Engineers has a committee which formulates tests for all electrical apparatus. At the present time the Institute does not recognize any circuit below 400 volts. That seems rather high for the average automobile installation.

E. T. BIRDSALL.—The tendency of the age is to make all of these materials as cheaply as possible. If we set a low limit and the producers come very close to it, which they probably will in the cheaper insulating materials, we will have trouble with it. I would not want to install any material based on a lower pressure than 1,000 volts alternating. Before I went into the automobile business I was in the electrical business, and a member of the Institute of Electrical Engineers. In the early days of electric lighting, we had a great deal of trouble, of course, with insulation. One of the main troubles the electrical engineers have at the present time is with the flimsy and low resistance materials which are on the market.

I would eliminate certain classes of insulating material that might under laboratory or factory conditions stand 600 volts. After being on a car in use a few months the chances are they would not stand anything like that test. A 1,000- or 1,200-volt material would be a great deal better at the end of a year's use. In an automobile the material is subjected to dampness from rain, washing and the ordinary course of driving.

### IGNITION

T. J. FAY.—Does this discussion include the ignition system?

PRESIDENT MARMON.—No.

T. J. FAY.—In view of the great importance of ignition systems and of the fact that while a good grade of high-tension cable will stand a

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breakdown test of upwards of 28,000 volts, the average spark plug departs this life under a tension of less than 3,000 volts, it is not easy to understand why this ignition problem is left out of consideration.

## INSTRUCTIONS FOR CARE OF STORAGE BATTERIES*

WM. H. PALMER, JR.—A subcommittee was appointed by the Electrical Equipment Division to formulate instructions for the installation and care of the storage batteries used in connection with electric starting and lighting systems; the feeling being that the various manufacturers were all, so far as instructions are concerned, saying about the same thing but in very different ways, and that if we could all get together and say the same thing in about the same words, matters would be simplified very much indeed. The subcommittee formulated instructions and submitted them to five of the companies who are most active in furnishing batteries for the work. The instructions were approved by those companies. The report is prepared and submitted herewith, as approved by the Standards Committee. The acceptance of the report by the Society will mean that these instructions will form the basis for the storage battery instructions used by the various manufacturers, each manufacturer, however, reserving the right to make such additions as may be necessary in order to make them cover completely any special battery construction.

### REPORT ACCEPTED

Summed up, the instructions amount to this:

> Install the battery where it can be easily gotten at. Secure it firmly on the car. Put water into it at regular intervals. For the rest, leave it alone.

(Upon motion, duly seconded, and put to vote, the report was accepted.)

### SIZE AND CAPACITY OF STORAGE BATTERIES

W. H. CONANT.—I would like to know whether there is any sentiment at this time for an effort to bring the sizes of lighting and starting batteries to a more uniform standard. As there is now a very wide variety, it is difficult both for the manufacturer of cars to obtain good deliveries and the manufacturer of batteries to supply them. The factors which determine battery size are the size of each plate, the number of plates, the number of jars, the arrangement of the jars and the position in which they are to be installed. I would like to see some effort made at this time toward standardization. The company I represent is willing to go to any length to meet the others in this effort.

Mr. President, I move that this matter of standardization of storage batteries for starting and lighting apparatus be referred to the proper committee for report and action at an early date. I should perhaps explain that in addition to the outside dimensions a basis of standard capac-

*For text of report, see page 2.

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ity rating is important. Every catalogue today shows a different rating for batteries that are of approximately the same capacity. If we can have a ten-hour or five-hour rate as standard, we can all work toward the same end to much better effect. I had in mind including that in this effort at standardization.

PRESIDENT MARMON.—Is the motion clear to you all, that it is the sense of the Society that the Standards Committee should attempt to evolve standard battery sizes and a standard method of rating batteries? The motion is before the house now.

(The motion was seconded, put to a vote and carried.)

## GENERAL REPORT OF STANDARDS COMMITTEE

PRESIDENT MARMON.—Mr. Souther, the chairman of the Standards Committee will make a general report.

### BROACHES DIVISION

HENRY SOUTHER.—In regard to the Standards Committee work in general, there is a great deal being done, but it seems to be advisable at this time not to bring some of the matters forward. In the matter of broaches we had a meeting the other night of the whole Standards Committee and discussed the proposed report very fully. It was sent back to the Broaches Division, with the idea of getting a more uniform multiple spline design. There is nothing further to report on that except progress.

### PLEASURE CAR WHEELS DIVISION

In the Pleasure Car Wheels Division the matter has come to a need of data as to the strength of rims. It is good to learn that the matter of weight in rims is at last attracting attention. It is quite possible that we shall get better materials and lighter rims than we have ever had before. But before taking any decided steps in this direction we must know the strength of that which exists. Two of our large rubber companies have come forward very generously and agreed to test all rims submitted. By tests I mean to actually blow the tire up and explode it, just exactly as would be done in practice. With the results of these tests before us we shall be able to tackle the pleasure car rim standard with a good deal more intelligence. I will only add that the demountable problem is going to be a hard one. Nevertheless, because of our efforts several of the companies have gotten together and I am informed unofficially that there are now several demountable rims that will go onto the same felloe band. That is progress, even if it is not a finish.

### MOTOR TESTING DIVISION

The motor testing division has nothing to report but progress. The work is in the hands of a most able committee, headed by Mr. Heinze, who are working out the many problems before them. They rather wanted to hear what our English brethren might say on testing and perhaps steal a few good things from them.

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MISCELLANEOUS DIVISION

Chairman Holmes, of the Miscellaneous Division, writes as follows:

The present committee started work in April when the matters that had been referred to it by the Council and the subjects left from the previous committee were turned over to it. About the first of May a meeting was held in New York. The following subjects have been and still are undergoing an investigation toward standardization:

Additional rod and yoke ends.

Length of threaded portion of S. A. E. spark plug.

Case-hardening boxes.

Threads for ball joints (such as are used in throttle and spark connections).

In regard to the rod and yoke ends a canvass is now being made to determine the approximate extent the new type would be used.

On the addition to the specification of the S. A. E. Spark plug, the committee believes some standard for the length of the threaded portion is desirable. The secretary is collecting data to show what is being used.

Most of the investigation of case-hardening boxes is finished. It seems that it would not pay to recommend any standards for these. This, however, cannot be settled for some little time.

The question of threads for ball joints has just been brought up. A canvass of present practice will soon be started.

On all matters that have come before the committee and probably all that ever will arise, it seems very desirable to conduct a thorough and careful investigation into what is being used at present, for it is useless to recommend any standard that will not be of benefit to the majority. The year's work of the committee is more likely to be made up of investigations the result of which will be negative in that the adoption of standards will not be recommended.

(Signed) A. HOLMES,
Chairman.

## NOMENCLATURE

PRESIDENT MARMON.—Mr. Coffin will present the report of the Nomenclature Division.

H. E. COFFIN.—Chairman Stoddard, not being able to attend the meeting, has asked me to say a word in connection with his report, which has been distributed among you. I think it will not be necessary to take up any of the points covered in this report, which is one rather of progress, except that I might point out that the chairman has asked for certain expressions from the Society. I believe that it is not advisable to have any discussion of these points at the moment.

I will read some correspondence which I think will be of interest as showing the progress that is being made.

In passing I might mention that the rubber interests have lately appointed a committee to simplify the nomenclature of the rubber industry. I have here a copy of a report which gives some forty or fifty terms to

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which the committee have reduced the nomenclature of the rubber business insofar as the designation of the quality of material and that sort of thing go. They are working along the same line that we are.

I have here some letters exchanged between Mr. Stoddard, the chairman of the committee, and Mr. Basil H. Joy, secretary of the English Institution.

(COPY)

DETROIT, MICH., December 27, 1912.

Mr. Basil H. Joy,
13 Queen Anne's Gate,
Westminster, London, W.

DEAR SIR.—The United States Patent Office is now classifying its patents relating to Automobiles.

I believe that the French Patent Office is also classifying its patents relating to that art.

The United States Patent Office has officially asked the Society of Automobile Engineers for coöperation in the work and the matter has been referred to a Nomenclature Division of the Standards Committee.

It would seem desirable that at least Germany, France, England and the United States have the same systems of classifying the patents relating to Automobiles. Can you use your influence, and that of the Institution of Automobile Engineers, to bring about an agreement that shall result in a uniform system of classification? If so, can we not agree between the respective societies so that a proper nomenclature shall be adopted in this classification, and each word have a definite meaning and be definitely convertible from one language to the other.

I am also writing to Germany and France.

Very respectfully,

(Signed) E. J. STODDARD,

*Chairman Pro Tempore, Nomenclature Division of the Standards Committee of the Society of Automobile Engineers.*

(COPY)

WESTMINSTER, LONDON, S. W., January 6, 1913.

E. J. Stoddard, Esp.,,
607 Moffat Block,
Detroit, Mich., U. S. A.

DEAR SIR.—I am very much obliged for your letter of the 27th ult. which I will bring before our Nomenclature Subcommittee of the Engineering Standards Committee.

I think the end you have in view is a most laudable one and will save a lot of trouble in the future.

Yours faithfully,

(Signed) BASIL H. JOY,

*Secretary, Institution of Automobile Engineers.*

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WESTMINSTER, LONDON, S. W., February 17, 1913.

E. J. Stoddard, Esq.,
607 Moffat Block,
Detroit, Mich., U. S. A.

DEAR SIR.—Your letter of December 27 last has now been considered by the Sectional Committee of the Engineering Standards Committee and your suggestions were very favorably received and the committee proposes to do their best to carry them out.

I think, therefore, it would be well if you would be good enough in future to correspond direct with the secretary of the Engineering Standards Committee, Mr. Leslie S. Robertson, 28 Victoria street, S. W.

Yours faithfully,

(Signed) BASIL H. JOY, *Secretary*.

H. E. COFFIN.—Then we have letters over the signature of Mr. Robertson, of the British Engineering Standards Committee, which represents, by the way, the standardization work of the Institution of Civil Engineers, the Institution of Mechanical Engineers, the Institution of Naval Architects, the Iron and Steel Institute, as well as the Institution of Electrical Engineers, and the Institution of Automobile Engineers also.

(COPY)

LONDON, March 7, 1913.

E. J. Stoddard, Esq.,
607 Moffat Block,
Detroit, Mich., U. S. A.

DEAR SIR.—With reference to your letter of December 27 last to Mr. Basil H. Joy, I should be glad if you could forward me in triplicate the latest Classification of the United States Patent Office in regard to Automobile Vehicles.

Thanking you in anticipation.

Yours faithfully,

(Signed) LESLIE S. ROBERTSON.

*Secretary, British Engineering Standards Committee.*

(COPY)

LONDON, April 8, 1913.

E. J. Stoddard, Esq.,
Society of Automobile Engineers of America,
1786 Broadway, New York, U. S. A.

DEAR SIR.—I beg to acknowledge receipt of your letter of the 29th ult., enclosing three copies of the proposed Classification of the United States Patent Office in regard to Automobile Vehicles. In regard to France and Germany, I am seeing what can be done in the direction of procuring the information you desire and shall hope to write you further on this point

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in due course, though you must be prepared for the delays which are inherent in communicating through official channels abroad.

Yours truly,

(Signed) LESLIE S. ROBERTSON.

H. E. COFFIN.—It is going to take a good deal of time to bring about results; undoubtedly a great deal of the matter will have to be handled by mail vote. It would seem impossible to have a general discussion at any of the meetings of the Society, when time is somewhat limited, on the use of particular terms as opposed to the large number of terms which now exist for the same motor car part or function.

PRESIDENT MARMON.—Mr. Wheeler, Councillor of the I. A. E., has a comment to make.

CHARLES WHEELER.—Mr. Coffin has saved me a great deal of talk by reading the correspondence that has taken place between the two sides of the water. I would only like to supplement his remarks by mentioning that the Engineering Standards Committee not only has the support of the Institutions he mentions, but it also receives financial assistance from the Government. The mention of this fact may be useful to you if you wish to bring pressure to bear on your State authorities.

The Engineering Standards Committee have taken in hand the subject of the standardization of automobiles and have appointed ten subcommittees. The subcommittee of which I have the honor of being chairman deals with Nomenclature; that is why I am now speaking. The only point I wish to bring to your notice is this: at our very first meeting it was proposed, seconded and carried *nem. con.* that no report should be made to our Sectional Committee, and certainly nothing should be published, until we had thoroughly discussed all points with your Nomenclature Division here; nothing whatever will go out to the automobile world until we have had a discussion. Consequently, if we cannot have absolute uniformity, at any rate there will be a minimum number of differences between our respective countries. I only wish to state now, sir, that you have my assurance that both the letter and spirit of that resolution will be strictly adhered to. (Applause.)

H. E. COFFIN.—It is believed that we shall have adequate coöperation in this country. In this connection the following are of interest.

### THE RIGHT NAMES OF THINGS

Attention is called once more to the desirability, if not necessity, of calling things by their right names. While it may seem a trifling matter, anything which allows of misinterpretation is always likely to cause confusion and results in the loss of time and money and perhaps the loss of future business.

It is not enough to say that most people know what you mean, for unless a definite name or term is adopted by all, there is still opportunity for confusion and its attendant loss.—*(American Machinist.)*

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(COPY)

The American Society of Mechanical Engineers

No. 29 West Thirty-ninth St., New York

E. J. Stoddard, Esq., Chairman, Nomenclature Division, Society of Automobile Engineers.

Dear Sir.—I am in receipt of your letter suggesting that the A. S. M. E. appoint a committee on nomenclature.

I think the suggestion is worthy of very serious consideration. I have been particularly impressed with the lack of uniformity in our nomenclature, not only in engineering, but in many other subjects. You refer to the French, Germans and English as also being weak in this direction. I have had considerable experience with the English and feel that they are infinitely ahead of us in this direction. I think that we in America are peculiarly loose in not only our nomenclature, but in our methods of expression. It is extremely easy for us to be misunderstood in discussing any moot question.

I shall be glad to act upon your suggestion to the extent of my influence. Yours sincerely,

(Signed) ALEX. C. HUMPHREYS,
Past-president.

# THE LONDON MOTOR OMNIBUS SERVICE

By T. B. BROWNE

(President, Institution of Automobile Engineers)

The motor omnibus seems to have made comparatively little headway as yet in this country and I have therefore thought that some details of the large and efficient motor omnibus service of London may prove of interest to you. According to the figures furnished to me by the courtesy of the Commissioner of Police, the number of motor omnibuses licensed during 1912 for use in London was 2,908, so that with the subsequent additions there are now more than 3,000 of these vehicles in use in the metropolitan area, as compared with about 1,000 in Paris. It may be of interest to state here in passing that there are over 8,000 motor cabs licensed in London alone.

The whole of the petrol propelled motor omnibuses running in London are now either owned or controlled by the London General Omnibus Co., and its subsidiary companies, including the Stevens-Tillings petrol electric vehicles which I shall describe later. The only independent company is the National Steam Omnibus Co., who construct and run the highly successful vehicles designed by one of our members, Mr. Thomas Clarkson, who is giving a paper devoted to them before this meeting.

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The first requisite for the successful use of motor omnibuses in competition with street tramcars is, of course, good roads and in this qualification London and its environs are now second to no other town and it is largely owing to this that the motor omnibuses have been able to compete so favorably with the electric trams or trolley cars as you call them here.

Two main factors have principally conduced to the present efficiency of the petrol omnibuses as now running on the London streets and these are firstly the insistence of the police authorities that the vehicles should comply with a high standard of noiselessness and reliability combined with a low maximum weight limit and secondly the determination of the constructors to produce vehicles capable of passing these tests. As an example of the difficulty of passing the police inspection of these vehicles it may be mentioned that cases have been known where vehicles have failed to obtain a license to run solely on account of the hissing noise caused by the passage of the air through the carbureter inlet, great trouble being caused by this defect alone until a suitable carbureter was discovered.

The police regulations as to weight, which are strictly adhered to, include the following maxima:

| | |
|---|---|
| Complete omnibus unladen | 7,840 pounds |
| Back axle weight laden | 8,960 pounds |
| Front axle weight laden | 4,480 pounds |
| Total weight laden | 13,440 pounds |

The three last figures include an allowance for sixteen inside passengers and eighteen outside, as well as the driver and conductor, of 140 pounds each. As regards dimensions, the total length must not exceed 23 feet and the breadth 7 feet 2 inches at any part, the maximum wheelbase being 14 feet 6 inches and the wheel track or gage not less than 5 feet 6 inches. There are also many other arduous but necessary regulations as regards brakes, steering gear, the prevention of smoky or otherwise offensive exhaust and leakage of oil from engine and transmission cases. Supporting bars have also to be fitted to minimize risk of danger from broken or falling parts such as cardan shafts and there are many strict rules as regards dimensions and other details of the body, also in reference to lighting, prevention of rattling, etc., etc.

It may be well to point out that at the present time there are still a certain number of the most successful of the older types of motor omnibus running in London which do not in every way comply with the latest regulations as regards the present weight limits which they slightly exceed but it has been the policy of the police not to deal harshly with the owners who have already received licenses for these vehicles under earlier regulations. The vehicles still running under this category belonging to the London General Omnibus Co., include 118 de Dions, having spur and bevel transmission and cardan shaft drives to the rear wheels, also sixty Straker Squires with chain-driven, change-speed gears, the power being transmitted to the road through worm gear and final chain drive.

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Plate 1.

Besides these there are some Leylands with spur change-speed gear and final live axle worm drive.

The chassis which has been specially designed by the London General Omnibus Co., and has stood the test of the strenuous regulations mentioned above is known as the B type. Of these, some 2,200 have now been constructed and put on the road and their reliability is shown by the charts giving the percentage of involuntary stops and those ordered by the police (see Figs. 1 and 2). The total distance covered by the London motor omnibuses per month is now averaging over 8,000,000 miles, the total miles lost from all causes by the B type vehicles for March last being 0.136 per cent. of the total possible mileage. The involuntary stops from all causes per 100 miles was 0.012 or say twelve stops for every 100,000 miles. In 1912 the total number of omnibus passengers carried in London was 492,858,934. Before starting to build its own chassis some thirty-two different kinds of motor omnibuses had been tried and used by the London General Omnibus Co., including petrol-electric, steam and petrol. Undoubtedly, one of the principal factors which have led to the successful results achieved has been the undertaking of the construction of the vehicles by the actual users, as in this way there is no clashing of interests between maker and user in tracing and removing defects and the experience gained in running and maintenance has been

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most valuable in arriving at the most suitable methods of design, construction and also in the choice of material.

A close alliance of this nature exists in every case where success has been attained, namely with the London General Omnibus Co., the National Steam Omnibus Co., and the Tillings-Stevens system.

In the case of the London General Omnibus Co., nearly 400 motor omnibuses have been supplied by the Daimler Motor Co., but these vehicles are a development of the B type mentioned above and the most important differences between these two chassis are mentioned later. The London General Omnibus factory at Walthamstow, which is capable of an average output of thirty vehicles a week as well as supplying renewal parts for 2,500 motor omnibuses, is one of the best organized in the British Isles, and has been laid out especially for the production of the one type of chassis with the consequent economy in the cost of production. The Daimler company have also organized a special department of their factory for turning out thirty omnibus chassis a week.

I have not time here to deal with the wonderfully efficient organization for the running and maintenance of the motor omnibuses and it must suffice to say that there are thirty-five garages with fully equipped repair departments attached, situated in convenient parts of London, controlled by the London General Omnibus Co. alone.

It will now be interesting to see in what way the various defects in the earlier vehicles have been overcome in order to comply with the stringent police regulations already mentioned.

Owing to the courtesy of Mr. W. J. Iden, chief engineer of the London General Omnibus Co., I am enabled to publish for the first time drawings showing details of the B type chassis as constructed by that company, though particulars of the chassis manufactured by the Daimler Motor Co. were published in *Engineering* in January last. It will not be necessary for me to describe the various parts in detail as the drawings are self-explanatory to engineers, so that I propose only to touch on the points which are of particular interest as illustrating the special requirements for an omnibus chassis as distinct from a lorry chassis designed for about the same load.

Glancing at Fig. 3 and Plate 2, one is at once struck by the comparative slenderness of the main members of the frame, the longitudinal members of which consist of 1¾-inch thick ash on either side of which are riveted 3/16-inch nickel-steel plates. These side members are of uniform depth for about half their length from the rear, the depth of the forward half being increased as shown. Although the average life of most of the parts of the B type vehicle is now known to its constructors, that of the frame has not yet been ascertained as none have yet had to be scrapped.

To account for this it must be remembered that the body which consists of an extremely rigid box-like structure is bolted to the frame and therefore acts very much as a stiffener to it. This combined wood and steel frame is said to be much superior to a pressed steel frame in reducing the noise from the transmission as heard inside the omnibus.

Another notable feature of the frame is its height from the ground,

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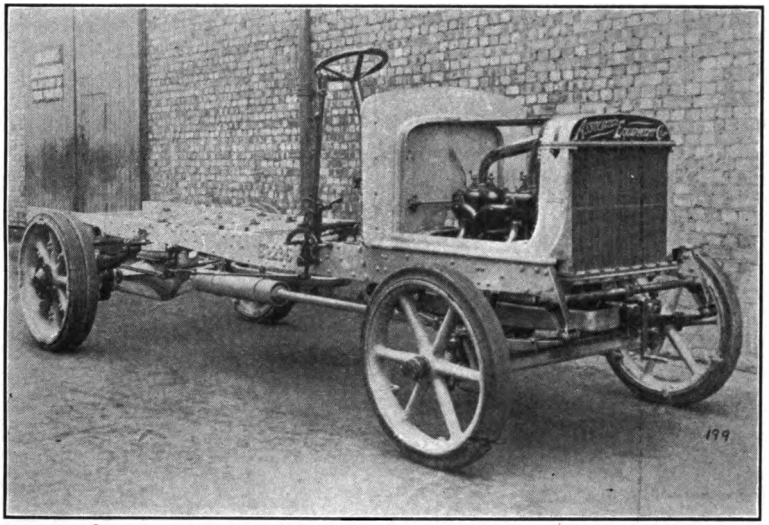

Plate 2.

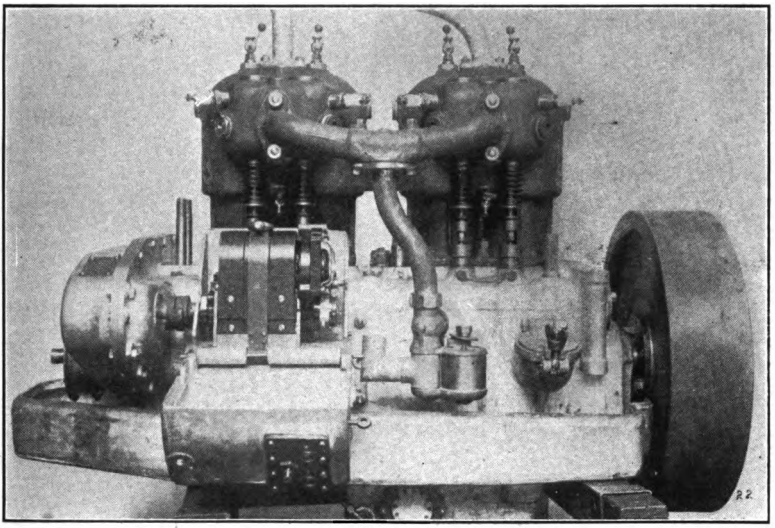

Plate 3.

namely, 2 feet 10 inches at the upper surface and well above the average height for motor vehicles. The main reason for this is to obtain a straight through horizontal drive from the crankshaft to the worm-driven live axle and at the same time to provide the ample clearance under the vehicle as insisted upon by the police. The diameter of the driving wheels is also a factor here.

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From Fig. 3 the general arrangement is easily seen and the simplicity of the design and absence of unnecessary parts are particularly noticeable One of the special features of the engine (see Fig. 4 and Plate 3), is the system of lubrication employed for the connecting-rod big-ends. This consists of troughs into which small scoops attached to the connecting-rods dip when at their lowest point and so pick up the correct amount of oil. Since this system has been adopted, all trouble from smoky exhaust has disappeared. One of the main differences between the London General Omnibus and the Daimler engine is that poppet valves are used for the former while the latter use a Knight sliding sleeve valve motor. With this engine it has been found advisable to arrange for the troughs to be slightly raised or lowered with the throttle so as to vary the amount of oil supplied, with the M. E. P. All engine bearings are of white metal and the main bearings are lubricated under pressure by means of a rotary pump.

The dimensions of the London General Omnibus engine are 115 mm bore by 140 mm stroke, the Daimler engine being 110 mm bore by 150 mm

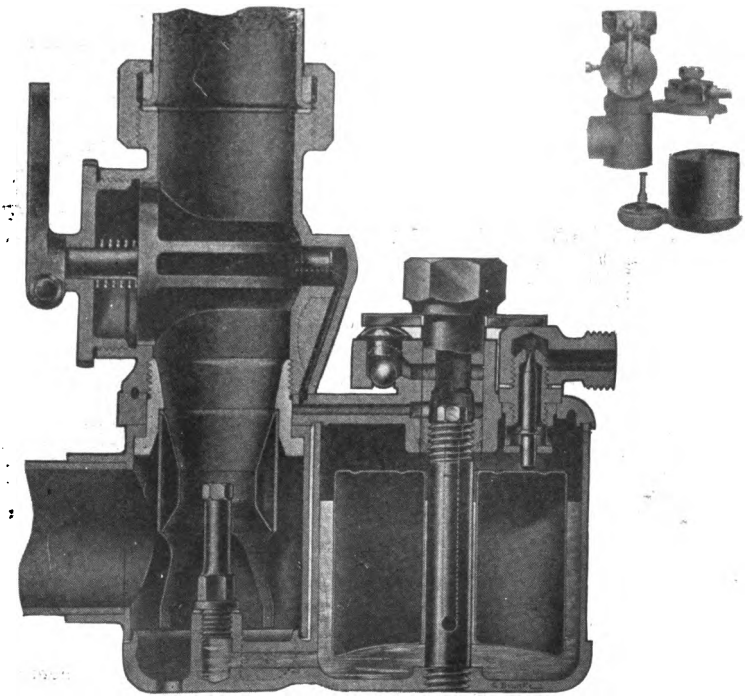

Plate 4.

stroke. Both engines have their valves actuated by saw-tooth chain-drive from the crankshaft and are not fitted with governors, the throttle being controlled by a pedal. The various pipes on the engines are made up

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from steel stampings in two halves which are welded together and have the flanges attached by the acetylene process, and are then lead coated inside and out which makes a very quick, clean and economical job.

The poppet valves of the B type engine have recently been enlarged from 36 mm to 42 mm. These valves are now made from mild steel and are case-hardened and ground all over. Formerly they were made from 10 per cent. soft nickel steel and only hardened at the tappet end so that the stem wore and caused leakage of air between them and the inlet valve guides which upset the carburetion and created a spitting noise by the escape of the exhaust in the same way. The London General Omnibus Co. rely on thermosyphon for water circulation but the Daimler company prefer to use a rotary pump. Both now use the same pattern radiator which consists of vertical copper tubes, the ends of which are expanded and soldered into the top and base tanks of the radiator. Bosch high-tension magneto is used on all engines. The magneto is enclosed in an aluminum case which the driver is not allowed to touch. (See Plate 3.)

The carbureter (see Plate 4) is of the two-jet type, the main jet being

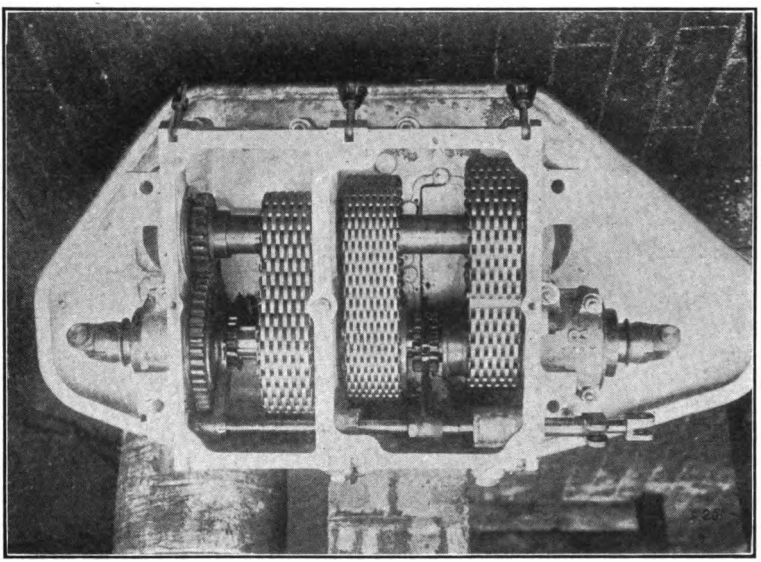

Plate 5.

fitted in the center of the choke tube in the ordinary way, and the auxiliary jet in the center of the float chamber. The throttle valve is hollow and the center chamber thereof is connected by a small passage to the auxiliary jet, so that when the valve is almost closed for slow running, the main jet is cut off and gas passes through the center of the valve from the auxiliary jet, the air passing through a ball valve shown in the photograph. Cold air comes in to the main jet from the bottom of the carbureter and hot air through the pipe shown on the left.

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The carbureter may be taken apart by unscrewing the nut shown on top of the float chamber, thus releasing the ring below it which holds the inlet connection in position. It also detaches the float chamber from the body of the carbureter.

With this carbureter the petrol consumption varies from 7 to 10 miles per gallon according to the nature of the route on which the vehicle is run.

The clutch, which is of the ordinary leather cone type, is fitted with a leaf spring as shown in Fig. 3.

The universal joints connecting the engine with the gearbox and the gearbox with the worm-driven live axle are of special design and are fitted with ball bearings to save wear on the moving parts which if plain bearing surfaces are used, are liable to rattle badly as soon as slight wear occurs. The Daimler company have been experimenting with a type of universal joint in which leather discs are employed to take the drive, the variations in the relative position of the two shafts being compensated for by the flexibility of the leather. This type of joint is, of course, not new as applied to fixed plant but is novel as regards its application to automobiles. I understand that its behavior has been such that it is likely to be adopted as standard practice for this type of vehicle by the Daimler company. It is certainly cheap and simple to manufacture.

The greatest difficulty in connection with the reduction of noise has been experienced with the change-speed gear. Extensive experiments have been carried out in the endeavor to minimize the sounds emitted by the indirect drives of the gears. The solution has been found by entirely replacing the spur wheels except in the case of the reverse, by silent sawtooth chain drives (see Fig. 5 and Plate 5). These have proved to be quite satisfactory in every way in spite of the fact that the chain makers themselves were very pessimistic as to their use. The salvation of the whole arrangement is the shortness of the chains, so that with the few links employed the total stretch of the chain with wear is very slight.

For some time great trouble was caused by the leakage of oil onto the roads from the crankcase, gearbox and worm gear case. It became necessary, in order to comply with the police regulations, to cast troughs below the joints to catch the oil which escaped from them. The joints were made as tight as possible by the use of brown paper but the mechanics when overhauling the chassis often displaced the paper, so that leaky joints were rather the rule than the exception. This objection has now been entirely overcome by having the joints carefully scraped up by hand and then fitted together without the intervention of any jointing material.

The B type worm-driven live axle is shown in Fig. 6 and Plate 6. Until recently it was generally considered that worm gearing could not be made to run at anything like the efficiency of bevel gearing and so it was used by only a few firms on account of its silent running but recent experiments at the British National Physical Laboratory and also by Brown & Sharpe have shown that by combining careful design with accurate workmanship and ball thrusts of ample size an efficiency as high as 95 per cent. can be obtained in actual practice; and so we find that all the

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motor omnibuses of recent design now running in London, including petrol, petrol-electric and steam are fitted with worm-driven live axles. Only the survival of the fittest can decide whether the Lanchester hollow worm or that of the straight pattern is superior. At present the former is only used on the Daimler buses of which there are now nearly 300 running in London under the control of the London General Omnibus Co. With the straight worm the double thrust can be fitted at one end to allow for expansion and contraction caused by temperature variations but with the hollow worm they must be fitted at opposite ends to keep the

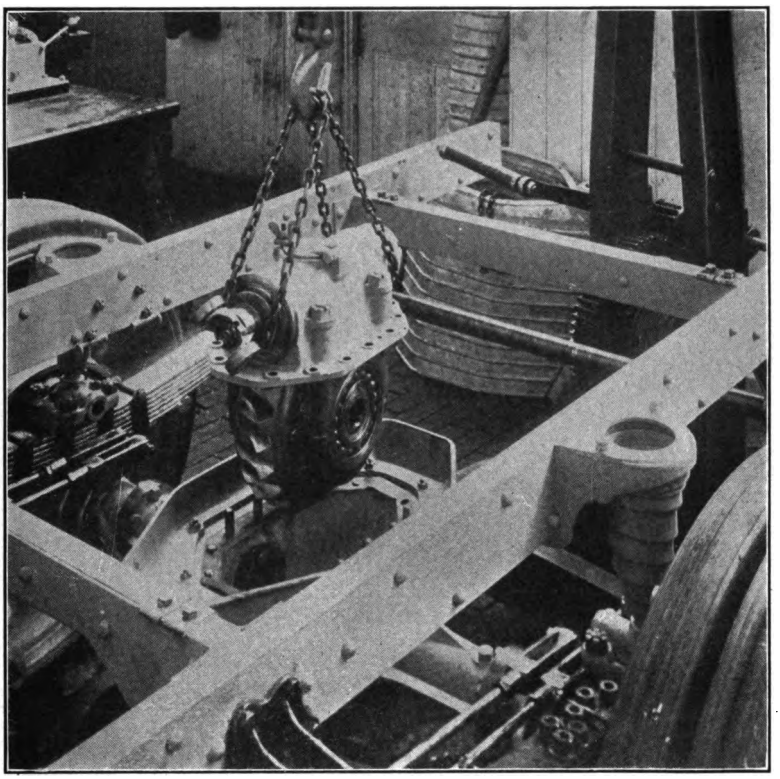

Plate 6.

worm in its correct relative position to the worm wheel. The axles of the two types are very much alike, the sleeves being bored from the solid. The Daimlers have hollow worms giving a reduction of 7¼ to 1 and splined keys are used wherever possible instead of single loose keys. The B type axle has straight pattern worm gear with a reduction of 7⅓ to 1, the worm having three starts and the worm wheel twenty-two teeth. In both types the complete worm gear is held in bearings fixed to the upper part of the axle casing which can be entirely removed with the

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worm gear by taking off a few bolts, the shafts from the differential to the wheels being inserted from the outer ends of the sleeves.

The live axle is designed so as to be easily removed from the chassis and an axle has been changed on the road in 45 minutes.

The Daimler company use roller bearings on both axles, the London General Omnibus practice being to use plain floating bushes of phosphor bronze.

The road wheels are made from special steel castings with hollow spokes; the weight of the rear wheels without tires is under 200 pounds

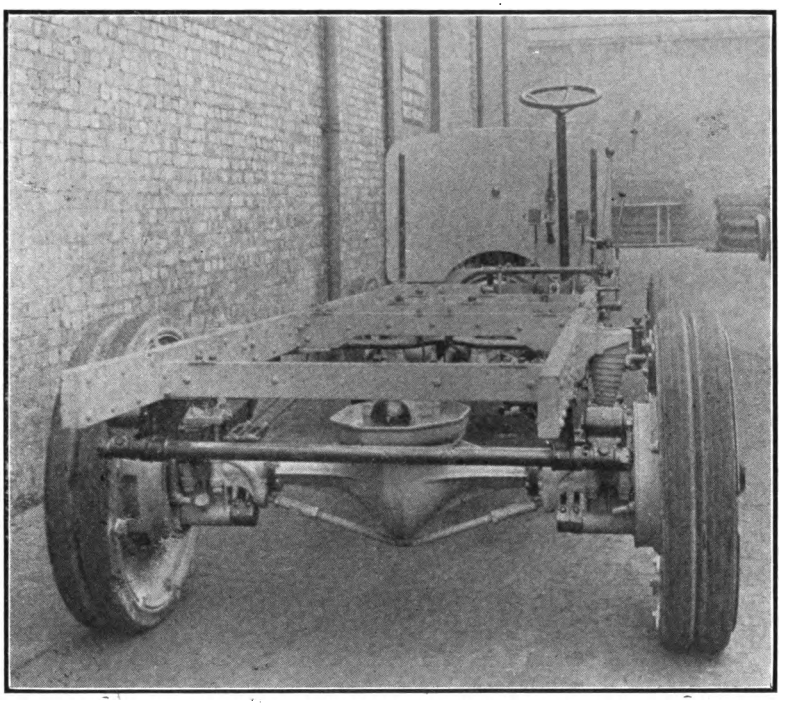

Plate 7.

each, that of the front wheels being under 100 pounds, including hubs and bushes. Various kinds of solid tires are used and are supplied by the tire makers who guarantee the mileage which averages about 20,000 per set of tires, the cost being about one penny per mile. Twin tires are used on the rear wheels and single tires on the front wheels, the standard dimensions being as follows: Rear wheels, twin tires, 100 mm by 1,000 mm; front wheels, single tires, 120 mm by 900 mm. These dimensions are practically limited by the maximum weight allowance as fixed by the police and it is probable that greater economy in wear of the tires would result if larger tires could be used to relieve the transmission

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of all braking stresses. Both foot and hand brakes are situated on the rear axle and are actuated by expanding shoes inside drums bolted on the rear wheels. (See Fig. 7 and Plate 7.)

A point of interest about the springs is the auxiliary volute spring fitted to the rear axle, so that it only comes into action after the leaf springs have taken about 70 per cent. of full load in the usual way (see Plate 7). The addition of this volute spring has added very greatly to the comfort of passengers, as it has overcome the difficulty of providing correct suspension for both a full and empty omnibus.

Throughout the chassis it has been necessary to use extremely high-grade materials to keep within the weight limit and comparatively few

Plate 8.

iron and steel castings are used, the complete list of these being the cylinders, road wheels, brake drums, steering box (two pieces), back axle casing, worm casing, two spring carriers, and the exhaust branch from the engine which cannot be made from a steel stamping owing to warping due to high temperature.

The steel stampings used comprise the flywheel, all frame brackets, including change speed and spring brackets; also the halves of engine pipes mentioned above.

As mentioned above there are about 120 petrol-electric motor omnibuses running in London, constructed on the Stevens-Tilling's principle (see Plate 8), in which the transmission from engine to the worm-driven live axle is by an electrical set, consisting of a compound wound dynamo, direct coupled to the engine, and a series wound motor coupled through a

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cardan shaft to the worm. The plan and elevation of the chassis are shown in Fig. 8.

The engine has four cylinders, 105 mm bore by 125 mm stroke, cast in pairs, high tension Bosch ignition, a Solex carbureter and the trough system of lubrication being used. The dynamo is connected direct to the engine by means of a flat leaf spring coupling, no friction clutch being used. No electric circuits are made or broken when driving, as the dynamo is designed to cease to excite when its speed falls below 300 revolutions per minute, so that by nearly closing the throttle, which is effected by releasing the throttle pedal, the torque of the motor is reduced to zero.

The dynamo is capable of a maximum output of 20 kilowatts at a speed of 1,400 r.p.m., with a maximum e.m.f. of 300. The control is effected entirely by the gas throttle pedal, except when ascending very steep hills, in which case a shunt resistance contained in the controller box is employed to allow of increased engine speed.

The dynamo and motor are of the semi-enclosed type and are ventilated by a disk fan carried on the rear end of the dynamo shaft, which as well as the motor shaft is carried on ball bearings.

The efficiency of the dynamo is given by the makers as 90 per cent. and that of the motor as 88 per cent., making a total of 79.2 per cent. efficiency of the electrical set.

The average running costs of these vehicles as supplied by the makers is given as just over 7d per mile (see Appendix I) and the author is of the opinion that this would be just about on a par with those of the London General Omnibus Company, but as the figure for running these vehicles has not been published this cannot be regarded as anything more than a guess. Some figures giving the details of running costs of the Paris motor omnibuses are given in Appendix II. These have been taken from an article which appeared in *L'Industrie des Tramways et Chemins de Fer* and are given there under all reserve.

The Paris omnibuses have developed on entirely different lines from those used in London and are of the single deck type, constructed to take from thirty to thirty-five passengers with the driver's seat situated on top of the engine. A spur gear change speed box, having three forward speeds, is used in conjunction with a bevel gear from which the power is transmitted through cardan shafts and internal spur gears or racks to the driving wheels, as it is not practicable to obtain the reduction required in a single beveled pair. The motor used in these vehicles has four cylinders, 125 mm bore by 140 mm stroke. The tires used are 140 mm by 900 mm single on front wheels and 160 mm by 950 mm twin on rear wheels. The weight of the chassis is 3,350 kilograms; the weight of complete vehicle empty, 5,100 kilograms; the weight of complete vehicle full, 7,800 kilograms.

In the space and time available it has been impossible to deal in any way exhaustively with any part of this subject but I have endeavored to put before you some of the most interesting and useful details in connection with the London motor omnibuses with a view to increasing your interest in this type of automobile.

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## APPENDIX I

Average running costs of "Tilling-Stevens" petrol-electric omnibuses, for 9 months, from January 4 to September 25, 1912. Figures supplied by the makers:

| | |
|---|---|
| Running | .868 |
| Maintenance | .240 |
| Tires | 1.098 |
| Drivers | 1.251 |
| Petrol | 1.067 |
| Lubricating oil | .078 |
| Grease | .018 |
| Paraffin | .021 |
| Lighting | .069 |
| Depreciation, rent, rates and taxes | .849 |
| Trade vehicles | .151 |
| Conductors | .847 |
| Body upkeep | .235 |
| Traffic expenses | .270 |
| Clothing | .001 |
| Pence per mile | 7.063 |

## APPENDIX II

Approximate running costs of Paris motor omnibuses as given by *L'Industrie des Tramways et Chemins de Fer:*

| | per kilometer |
|---|---|
| Maintenance of chassis | Fr. 0.1300 |
| Maintenance of bodies | 0.0300 |
| Maintenance of tires | 0.1200 |
| Cleaning, lighting and heating of vehicles | 0.0265 |
| Fuel (including 15 fr. 20 octroi duty per hectrolitre) | 0.2125 |
| Oil, grease, etc. | 0.0210 |
| Mechanics | 0.1000 |
| Depot expenses | 0.0600 |
| Total | Fr. 0.7000 |

NOTE.—The above does not include reserve for renewals, wages of drivers, conductors, or inspectors, insurance, accidents, etc.

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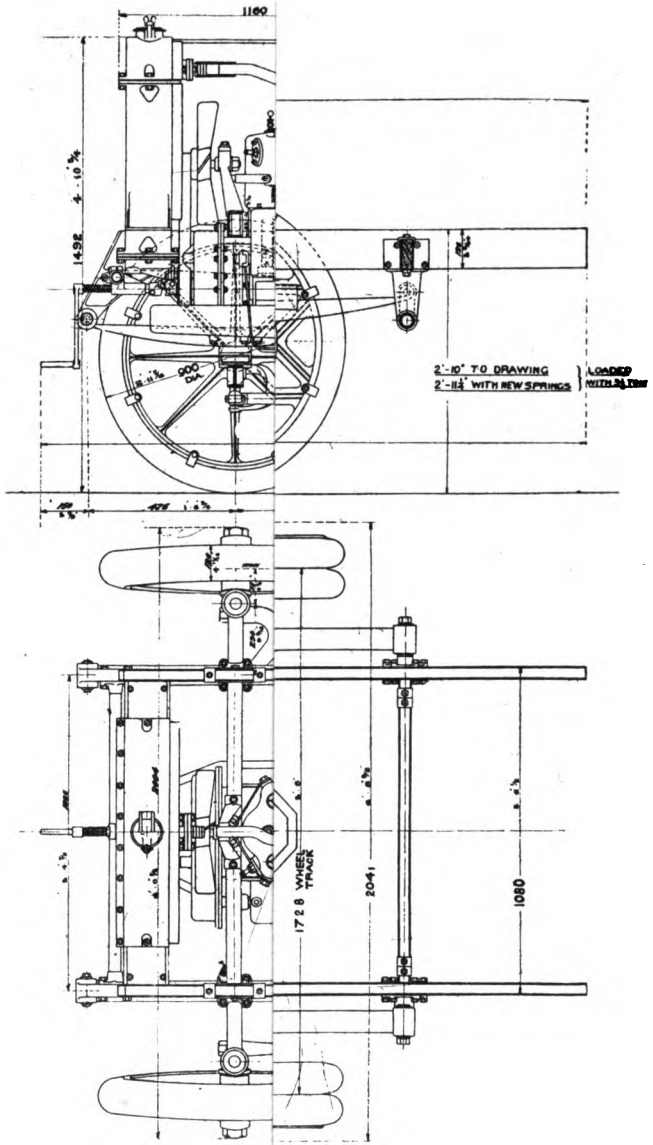


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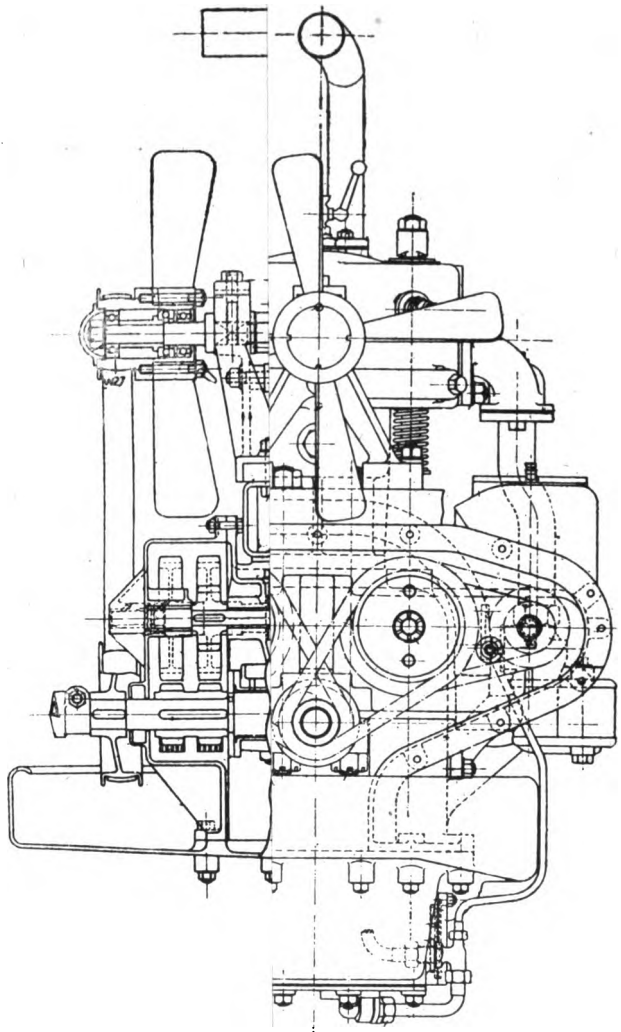

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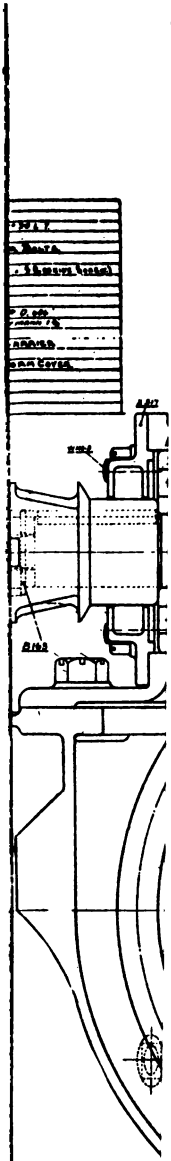

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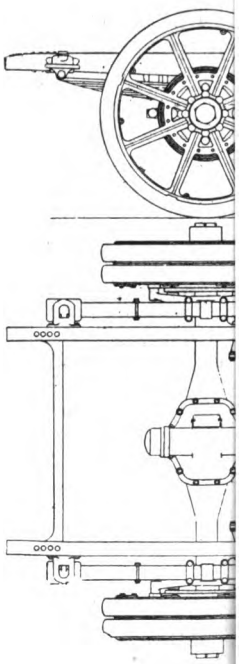

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## DISCUSSION.

PRESIDENT MARMON.—It is but rarely that the Society has been favored with a paper so full of interest. It is now open for discussion.

N. B. POPE.—Mr. President, it is exceedingly thoughtful of President Browne to provide us with this great wealth of most useful and complete information in a field in which the British industry excels and in which our industry is, if anything, weak. The fact that most of this information has been hitherto unpublished increases, of course, its value to us very much, and adds to the compliment which President Browne has paid us in providing its compilation for the records of the Society of Automobile Engineers. I therefore move you that we tender him a hearty vote of thanks for his courtesy.

(The motion was seconded by Mr. Souther, and carried unanimously by a rising vote.)

N. B. POPE.—One of the slides shown indicated the arrangement of the volute auxiliary suspension of which Mr. Browne spoke the other day in conversation, when he brought out a point concerning the construction of that spring, which is not obvious and which rather interested me. Perhaps I may ask him to explain that. I refer, sir, to the cutting away of a portion of the spring to render the displacement uniform, as the load is increased.

PRESIDENT BROWNE.—I think that the end of the spring is simply tapered away.

PRESIDENT MARMON.—I would like to ask Mr. Browne whether that volute spring is so wound that it imposes upon itself to produce a friction by the binding as it gets near its final set, or is free all through its movement?

PRESIDENT BROWNE.—It is practically free all through its movement.

THOMAS CLARKSON.—There is only one point upon which I would like to touch in connection with Mr. Browne's excellent paper, as I shall be occupying a little more of your time later on—the figures with respect to the percentage of mileage lost and the total possible mileage do not appear to take account of the fact that it is the custom for companies running petrol buses to withdraw every bus from service one day in ten. Therefore, to the percentage which Mr. Browne has given us 10 per cent. should be added in order to give us a correct idea of the performance. The expression "total possible mileage" truly means that every bus does full mileage each day for 365 days each year. This is the mode of reckoning adopted by the company with which I am connected. Reckoned upon this basis the London General Omnibus Company's mileage does not appear to reach 85 per cent.

PRESIDENT BROWNE.—With all respect, Mr. Clarkson, I think this question of withdrawal is largely a matter of policy. Some makers prefer to wear their buses out sooner or run them longer before they take them off. It is simply a question of policy, probably due to the local peculiarities and not from theoretical considerations. I think myself the only way to compare a steam vehicle with the petrol motor omnibus would be

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to get exactly equivalent chassis in every way except in the parts which directly concern steam or petrol. I would like very much to take twenty or Mr. Clarkson's motor omnibuses and twenty of the London General omnibuses and fit them alternatively with petrol and steam-engine and transmission gear, running the twenty buses against twenty of the other type, at least 10,000 miles on exactly the same conditions with the same loads. I think that is the only way in which you would be able definitely to settle which is the most economical method. Probably the result will be that for some purposes the steam bus is best, for others the petrol. Small differences in the load, in the route and other matters will cause the one or the other to come out on the top.

WILLIAM P. KENNEDY.—I would like to ask Mr. Browne if there is any significant difference in the first cost of the two equipments, the petrol and the electric.

PRESIDENT BROWNE.—The petrol-electric must certainly be more expensive. They are at present made only in small quantities. But even if made in larger quantities the petrol-electric must come out more expensive than the ordinary straight transmission.

PRESIDENT MARMON.—Mr. Browne spoke of the police regulations, the rattle of the steering-gear being referred to. Do you mean that that steering gear is listened to with a good deal of attention or must it be so noisy as to be quite audible? Is the same handicap, if it is to be called a handicap, put on the private car? Must it be equally quiet?

PRESIDENT BROWNE.—There is no regulation as to the quietness of the ordinary private car. The steering of the buses is very closely inspected by the police.

DAVID FERGUSSON.—May I ask if there is any particular reason for changing to the hollow-spoke steel wheel instead of the cruciform section which the London General Omnibus Company appear to have used prior to the latter one that you have just shown?

PRESIDENT BROWNE.—I think there was a very good reason for that. The failures were fairly considerable; that was the reason for the change.

A MEMBER.—Can you tell us where the center of gravity of the L. G. O. omnibus is when it is full on top and empty inside?

PRESIDENT BROWNE.—I have not that information with me. The height of the center of gravity is about 1500 m/m above the road on the B type buses, when fully laden.

A. E. BRION.—Have the hollow wheels proved very satisfactory?

PRESIDENT BROWNE.—They have, very satisfactory, and I believe the Daimler Company are looking for something better still. I would like to say in reference to this, the shape of the spoke has been altered since that illustration, so that the taper increases in the other direction; the reason being the stress produced in cooling is less that way.

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# STEAM OMNIBUSES

By Thomas Clarkson
(M. I. A. E.)

## INTRODUCTION

In order to avoid misconception with respect to my attitude toward the internal combustion motor using spirit fuel, permit me at the outset to state that I fully appreciate the enormous utility of this type of motor in certain departments of automobilism—that my strictures upon it as applied to bus work should not be regarded as the outcome of a prejudiced judgment but rather as an impartial scientific analysis of the special conditions applicable to bus work and heavier automobilism. This to the end that other fuels besides spirit should be utilized such as kerosene, crude oil, coal, or coke, thereby easing the demands upon the spirit motor and its fuel supply, and leaving it greater freedom of development along its special lines of utility.

## PASSENGER TRANSPORT FACILITIES

Increased facilities for passenger transport in cities are constantly in demand. Transport by electric rail motors, both on the surface and underground has, to some extent, met this demand. But the automobile public service car, or as it is generally called, the motor bus, has already demonstrated its superiority over the rail car or tram.

The main points in favor of the bus over the rail car are its flexibility and independence of action. Flexibility is the dominant feature, flexibility of route, both as to deviations, extensions and modifications according to traffic conditions, and also flexibility of control in traffic, especially rapid flexibility of speed so as to accelerate promptly in response to traffic conditions whether congested or otherwise.

Complete flexibility is obviously impossible so long as the motors are dependent upon an extraneous power station. The vehicles must be self-contained and the power generated from within. Flexibility I regard as the keystone to the successful solution of the street traffic problem in cities, and I submit that the type of motor which gives most flexibility with the least trouble and expense is the type which will make good. Hence my preference for the steam motor bus in its present perfected form.

A properly constructed steam motor possesses a reserve of energy which is immediately available for a spurt, and acceleration can be speeded up smoothly and without jerk or inconvenience to the passengers.

The control by the driver of a steam motor is simplified and the demands upon his energy and nerve force are reduced to a minimum. This last has an important bearing upon the prevention of accidents and loss of life. The speed is entirely controlled by a foot throttle and no change gears are used.

The weight of a fully laden standard London bus is 13,440 pounds.

The unladen weight is 7,840 pounds.



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This is about 2,000 pounds less than the former weights of both internal combustion and steam buses of the same carrying capacity (34 passengers) which were common a few years ago. This substantial reduction in weight has vastly improved the breed of the bus, for which thanks are due to the police authorities for insisting upon a lighter construction in order to obviate damage to adjacent properties consequent upon severe road vibrations. It was prophesied that this police demand would rule out the steam bus as it did the storage battery electric bus. But it is significant that the first bus to be licensed under the new régime as to weight was a steam bus; as a matter of fact No. 5 National. This was nearly 4 years ago. I claim that the steam bus is still the best, the most efficient and popular, and this view is shared by some of the leading traffic men who control internal combustion motor buses. It is noteworthy that every one of the companies running internal combustion buses in London have been unable to stand the competition of their largest petrol omnibus rival, and have all been absorbed. Today the only omnibus company able to maintain its independence of the great omnibus combine in London is the company running steam omnibuses. The advent of the motor omnibus appears to sound the death knell of the street rail car. The public shows a decided preference for the motor bus and the reason is not far to seek. The bus, owing to its greater freedom and flexibility of action, is easily able to beat the rail car in carrying passengers to their destination in the shortest possible time. Another advantage of the bus is that it can pick up and set down at the edge of a sidewalk instead of requiring passengers to walk in the roadway to or from the car. As a rival to the street rail car the motor omnibus has become a very serious proposition, and the perfected motor omnibus should be of immense value in solving the street traffic problem of cities. The presence of rails in the surface of a common road all automobilists will agree is detrimental to the efficiency of the road surface, and to the vehicles using the road.

The following summarized description will explain the leading points of the National steam bus:

The fuel is kerosene which is vaporized, mixed with air and burned beneath a water tube generator.

The generator is entirely of steel and works at a pressure of 300 pounds (test pressure 1,000 pounds). The generator is enclosed in a vertical cylindrical case under the bonnet of the chassis. The generator has a central drum which is closed at the lower end, and fitted at the upper end with a lid for cleaning. The drum is furnished outside with generating tubes of horseshoe form which permits free expansion without strain.

The steam is manufactured in four successive stages:

(a) A preliminary heating of the water to about 140 degrees.

(b) A secondary heating of the water under pressure to about 400 degrees.

(c) Conversion of the heated water into steam at 300 pounds pressure.

(d) Superheating of the steam to about 800 degrees.

The steam is utilized in a simple engine, two-cylinder double acting reversible, which drives the rear wheels of the chassis direct through

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worm gearing at a ratio of about 7 to 1. There is no clutch and no change gears.

The exhaust steam is condensed, filtered and returned to the tank for further use.

The fuel consumption is regulated automatically by steam pressure. The success of the National steam buses is doubtless due in great measure to the excellent "fool proof" generator.

Time does not permit me to refer to the springing, steering, axle construction or brakes of the chassis which are upon standard lines, but there is one detail of the construction of the National bus which calls for special notice, *i.e.*, the wheel.

The life of a motor bus is extremely strenuous, probably the most strenuous of any automobile. Its annual mileage is about 30,000. Most of this is done on roads teeming with other traffic; consequently a bus has to stand hard knocks and rough usage. Wooden artillery wheels have proved unequal to the duty. Wheels constructed of cast steel have proved troublesome and uncertain. The National bus road wheel is constructed entirely of forged steel. The spokes are solid drawn tubes welded to a hub which is machined out of a solid forging. The outer ends of the spokes are welded to flanges which are afterwards machined before the rim is shrunk on. The perfect balance of this wheel and the reduction of about 170 pounds in the weight of the four wheels of a bus have materially reduced the wear on tires, and the absence of any internal stresses in the wheel is a great factor in reliability and public safety.

## ILLUMINATION OF THE BUS

The proper lighting of a bus has been a troublesome problem, neither oil nor acetylene having proved satisfactory. Electric illumination gives best results. The problem has been to devise suitable electric equipment. This problem has been solved on the steam bus in a very simple and satisfactory manner. About 10 years ago I experimented with electric light for bus illumination. The first equipment was worked from a storage battery, but it did not pan out and electric lighting was discarded. Subsequently a scheme was devised whereby a small storage battery was used in combination with a special dynamo driven by the car and with cutouts similar to lighting systems now used on some pleasure cars. After running this combination in service for several years I abandoned it in favor of a dynamo of the ordinary type directly attached to a small steam motor and without batteries or cutouts. This steam motor runs at a constant speed of 900 r.p.m., and the equipment provides current for 150 cp. per bus. The arrangement has proved completely satisfactory. The cost and weight of the installation have been reduced as well as the cost of maintenance; at the same time greater brilliancy of illumination has been secured. Excellence of illumination has proved a bull point in popularizing the steam bus and in helping traffic receipts.

Some steam buses of the earlier type have been in regular service for the past 10 years and are still running. But the steam bus of today has

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been evolved during the past 2 or 3 years since the designer and manufacturer took up the business of running buses and maintaining them.

In the short time available for this paper it is impossible to give a history of the evolution of the modern steam bus upon which I have been engaged for nearly 20 years, and as the main object of this paper is to promote a discussion on the relative merits of steam and internal combustion buses, I will briefly summarize a comparison between these two types of motor.

SUMMARY

*The First Cost* of the bus appears to be about equal for the same quality of material and workmanship and with a similar rate of production.

*Cost of Maintenance.*—It has so far been impossible to obtain figures which are strictly comparable as to the relative maintenance costs of the two systems. The only way to obtain them would be for the same auditors to examine and analyze the books of both a steam bus and an internal combustion bus company, and to treat both in precisely the same manner as to depreciation, annual overhaul, establishment expenses, etc. Experience shows that the steam bus is in the garage for maintenance a much shorter time than its rival. It is the practice to withdraw an internal combustion bus from service one whole day in ten for maintenance, apart from the withdrawal from service for annual overhaul which usually takes about 2 weeks. On an average during the year the internal combustion bus loses more than 15 per cent. of its total possible mileage. Total possible mileage means every bus that is licensed doing every journey every day for seven days a week throughout the year. During the year ended October 31, 1912, the National steam buses lost only 2.847 per cent. of the total possible mileage, and of this only .877 per cent. was due to mechanical failure. That it has been possible to run steam buses under the extremely strenuous conditions prevailing in London so as to give over 97 per cent. of their total possible mileage, whereas the internal combustion bus is not able to do 85 per cent., speaks eloquently both for the superior reliability of the steam bus and its cheaper maintenance.

*Tires.*—There is less wear on tires with the steam bus owing to the smooth drive.

*Rapid and Smooth Acceleration.*—In this respect the steam bus is easily demonstrated a winner. The extra steam pressure which accumulates at each stop gives an extra "push off" at re-starting.

*Flexibility and Speed.*—In this respect also a superiority of the steam bus is demonstrated daily.

*Illumination.*—The steam bus is admittedly the most perfectly illuminated.

*Popularity.*—The public shows decided preference for the steam bus.

*Vibration and Jerk.*—There is less vibration on the steam bus. The engine does not run when the bus is stationary for picking up or setting down passengers, and there is no uncomfortable jerk at starting.

*Depreciation.*—Steam buses which I started in regular public service over 9 years ago are still running. I cannot find any internal combus-

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tion buses which have been in service so long. My rule for estimating depreciation is to give a 6 years' life, and at each annual overhaul to bring the bus right up to date.

*Fuel.*—A steam bus uses kerosene fuel and so helps to relieve the pressure on the spirit market. With equality of ratio between

$$\frac{\text{price of kerosene}}{\text{price of spirit}} \quad \text{and} \quad \frac{\text{mileage on kerosene}}{\text{mileage on spirit}}$$

there is nothing to choose between either type in cost of fuel. The great increase in the demand for spirit and the absence of a like increase in the demand for kerosene favors the kerosene fired steam bus.

*Drivers* prefer the steam bus on account of less fatigue in operation and greater certainty of completing the journeys. Drivers are paid by the journey.

I will conclude the summary by giving the actual figures for lost mileage from all causes during the year ended October 31, 1912, for the fleet of National steam buses in London.

| | | |
|---|---|---|
| Buses withdrawn from service for annual overhaul..... | 1.844 | per cent. |
| Buses withdrawn from service for passing drivers..... | .045 | " |
| Buses withdrawn from service for police stops..... | .023 | " |
| Buses withdrawn from service as a result of accidents.. | .058 | " |
| Buses withdrawn from service in consequence of mechanical failure ..... | .877 | " |
| Total, from all causes..... | 2.847 | " |

I think it will be agreed that these figures are remarkable, especially in view of the fact that the loss of service due to mechanical failure was well under 1 per cent., having regard to the exceptionally severe conditions of the service.

During the above period over 15,000,000 passengers were carried on the steam buses.

It must be obvious that a steam motor which gives such results, under the abnormally severe conditions of public omnibus service, should have useful work to do in other departments of commercial automobilism, say for net loads of 3 tons and over. And it is important to note that for this work the steam motor can use coal or even coke fuel. In this manner a large section of commercial automobilism can be placed right outside the range of the oil trusts which now dominate the fuel supply, and commercial transport of first-class reliability can thus be supplied at a lower working cost than is possible under present conditions with the internal combustion motor.

(Slides were shown and explained by Mr. Clarkson.)

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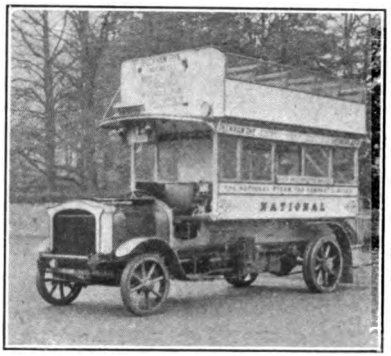
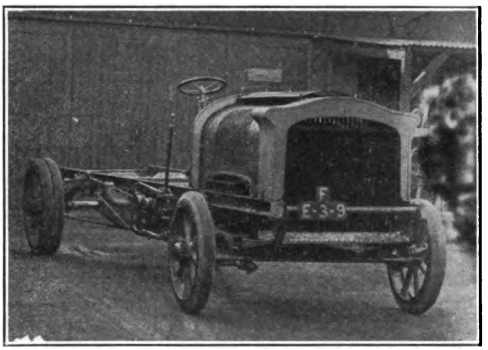
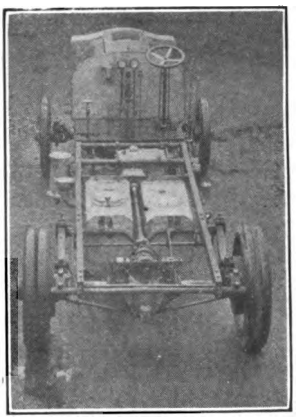


Two Views of National Steam Bus

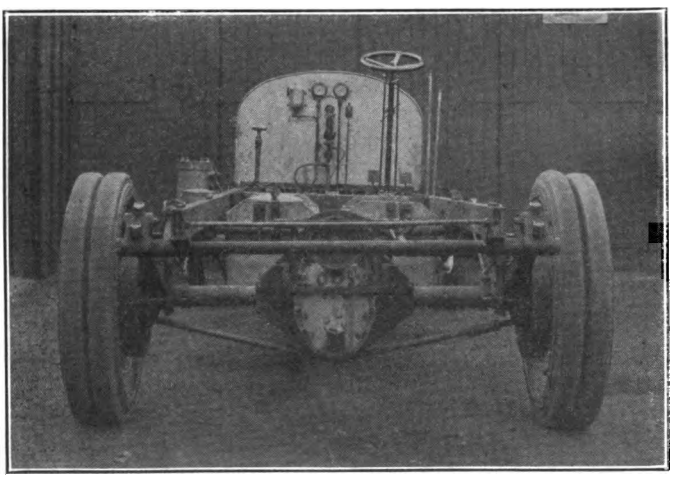



Front View



Top View

VIEWS OF THE CHASSIS



Rear View

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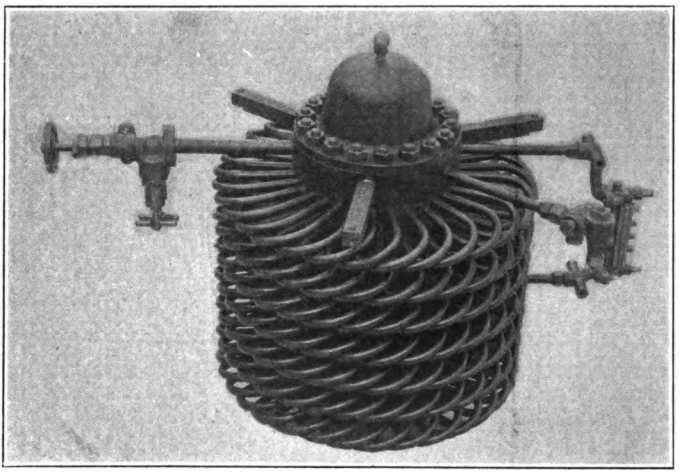
The side view of the chassis shows the filter for the water of condensation. The water of condensation passes through here before going to the tank, and in this is collected the cylinder oil. We have been able to collect and use over again the cylinder oil in this way.

On the subject of lubrication we have had a great deal of experiment to find the most reliable oil for a superheat of 800°. It should be an oil that will easily filter from the water of condensation. We employ an oil which is practically pure mineral hydrocarbon, and to this is added 2 per cent. of neatsfoot. Since this was adopted the results have been very satisfactory.



The Generator

This is the generator, with the central steel drum coming right down. It is just visible. The cover is removable for cleaning. The whole thing is carried on three arms, which are screwed into the top of the drum. This center drum is forged from one piece of steel under a pressure of two and a quarter million pounds (1,000 tons). The whole boiler is tested to 1,000 pounds per square inch.

These boilers will stand very hard punishment and they get it. Sometimes the driver, a new man usually, will not know whether he has water in the tank, and the next thing he has the boiler red hot. He does not make any trouble about that. He puts in water and goes on again. It seems remarkable that these boilers will stand such treatment. Another thing, the London water is very highly mineralized (about twenty-two or twenty-three degrees of hardness). This boiler can be easily cleaned out with cheap labor, and a flexible cable passed through the tubes; otherwise it would soon not be possible to run it at all. We are now putting in a softening plant to save boiler cleaning, and in another garage we are boring a well. The bore had reached about 450 feet before I left, and we got a supply of water having only 3.5 to 4 degrees of hardness. It

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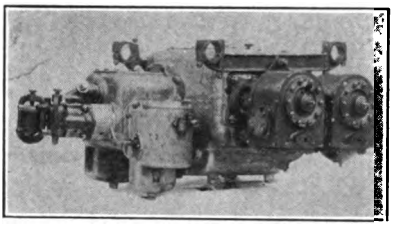
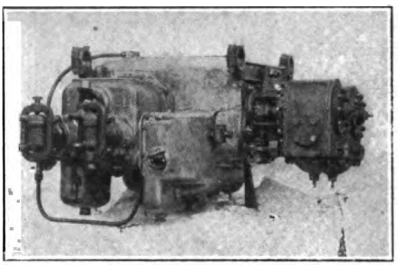
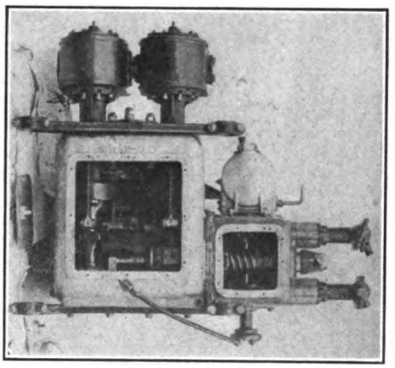
seems remarkable that in London, where the general water supply is so hard, by going deeper an excellent supply of extremely soft water is obtained.



Side View



Rear View.



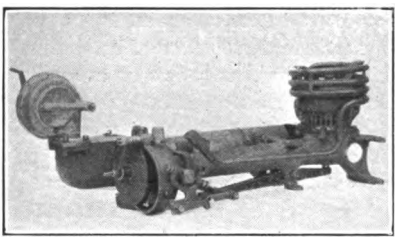
VIEWS OF THE ENGINE

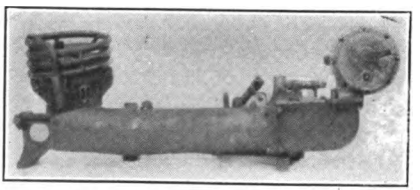
Pumps for fuel and water

Top View

These illustrations show the engine, the two cylinders and crank chamber. I am glad to say that the valve gear is the Joy, designed by the father of our esteemed Secretary. (Applause.)

The two pumps for kerosene and water, driven by a small cross shaft with worm drive at reduced speed, are shown. There is a cylinder lubricator also operated mechanically.





Kerosene Burner with Starter

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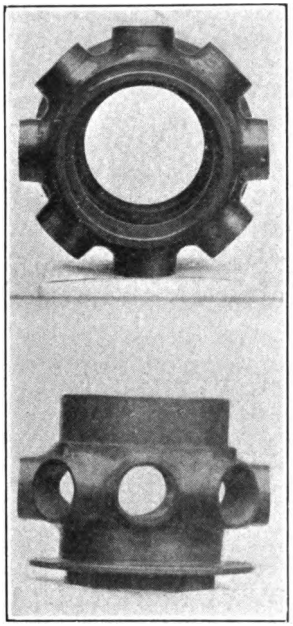
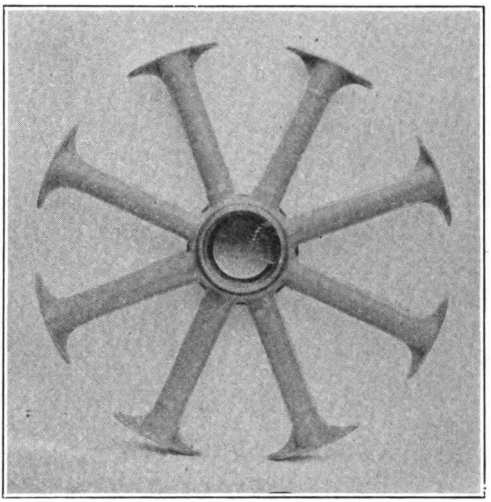
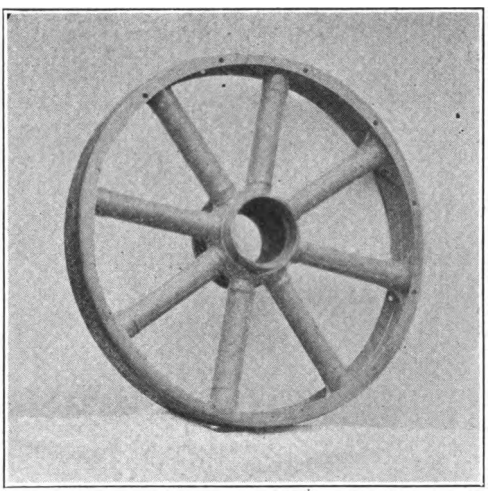


Views of Wheel Hub



Hub with Spokes Welded



Wheel with Rim in Place

The kerosene burner with the starter is shown on the foregoing page. It is a Bunsen type burner. The vaporizing coil is above the ports out of which the mixture of vapor and air escapes, and where it is burnt. The oil enters

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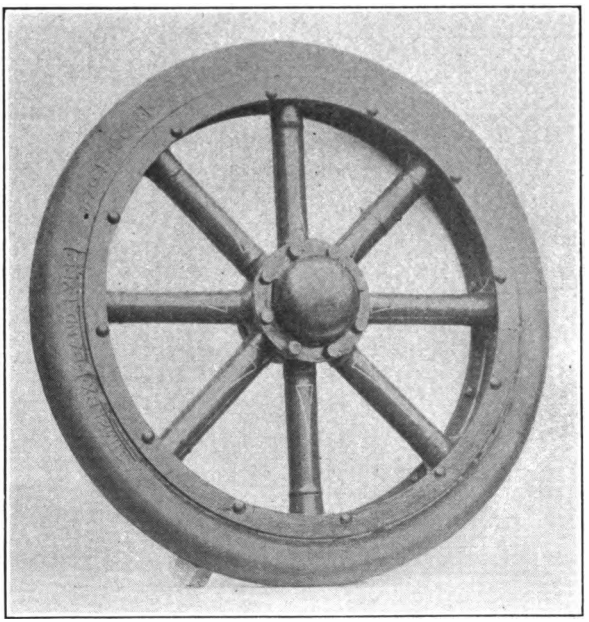
at the lowest end of the vaporizer, passing upwards through the coil, then descends to the mouthpiece of the inducing tube and so to the Bunsen burner. The burner can be started up from cold in about a minute. In one view the damper for shutting off the air when the burner is extinguished, is shown.

Now we come to the wheel. You get an idea of the thickness of the hub from the elevation. The main bosses are for receiving the races of the bearings. We have subsequently made a difference in the style of the hub so as to facilitate interchangeability, taking various sizes of bearings and leaving the standard parts of the wheel all alike.

HENRY SOUTHER.—That is a drop forging, is it not?

THOMAS CLARKSON.—Yes.

Another view shows the wheel with the spokes welded on. They are butt-welded and so a uniform section of material is preserved. There is no sudden change in the section, as would be the case where spokes are socketed. The spoke flanges are also drop forgings butt-welded on, and the whole is machined on the outside and can be heat treated. It is important to note that every spoke can be tested before the rim is put on. Thus it can be proved that each spoke is sound and not subjected to internal strains like the spokes of a cast wheel. This wheel can be repaired, which is not possible with the cast wheel.



Front Wheel with Rubber Tire

The rim is in two halves, of angle section. This forms a convenient flange for securing the retaining flange for preventing the tires coming

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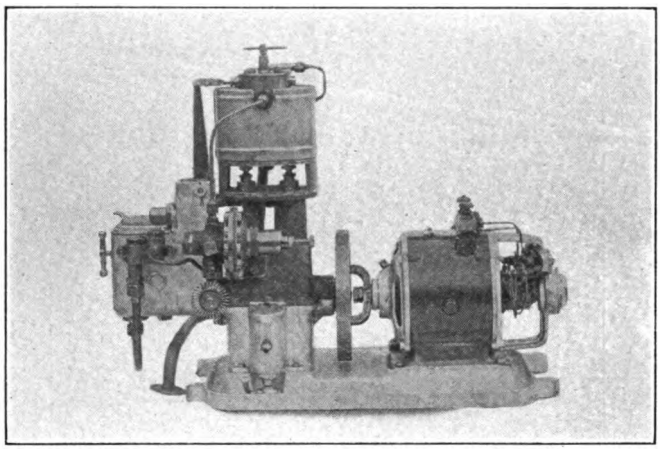
off. It forms a very light construction. The first pair of these wheels we made were run with ordinary plain steel tires on a chassis of about six tons weight. We drove that chassis over thirty miles an hour on the ordinary road with solid rubber tires to see if we could break those wheels; after that test the police allowed them to be run in service. When they had run over twenty thousand miles in daily service the police commissioner sanctioned their adoption on all our buses. I have already mentioned that the reduction in weight of those wheels has been a great factor in the tire bill.

The single-deck buses were very popular but were a failure for one reason. They did not carry people on the top, and that is what the people insisted upon in London. Another thing is that in consequence of that they had not the earning power. They had a seating capacity of only about fourteen against thirty-four on the double-deck bus of today.

There was a double-decked bus in which the driver was placed over the generator, as is done in some of the types of electric and gasoline motors today. This was an intermediate stage in the development. The unladen weight was 4½ tons. A similar type of bus was used by the London Road Car Company in 1904.



The Lighting Engine and Dynamo

There is the little lighting engine and dynamo that do the whole of the lighting on our buses today. It has an aluminum bed-plate; ordinary type dynamo, two cranks opposed, 180 degrees, the cylinders single-acting. We do not run trunk pistons. There is one little valve in the top of the chamber for both cylinders, operated by a rocking lever, the other end of which works in a groove in the crankshaft. It works at about nine hundred or a thousand revolutions a minute and is practically silent. There is a pump for forcing lubrication into the engine. There is also a reducing valve. You see the boiler pressure is bound to fluctuate.

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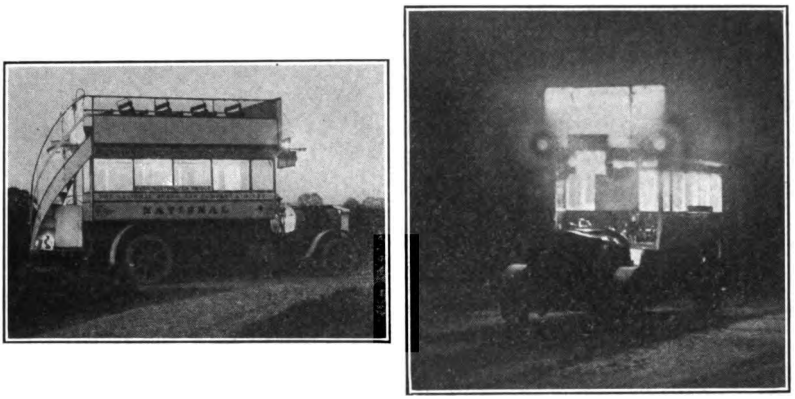
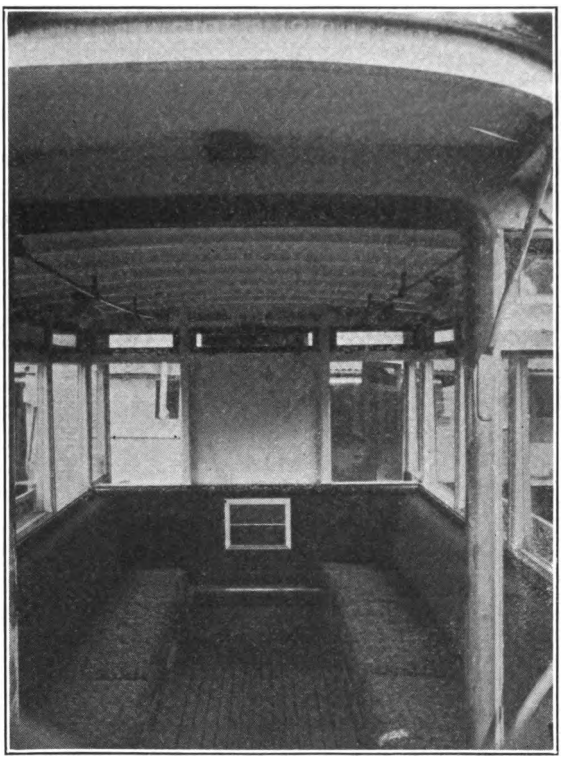



Illuminating Effects



Interior of National Bus—from Rear Entrance

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A car will run with any steam pressure from 150 to 450; usually it stays pretty steady between 300 and 350, but if you have been running fast or climbing a steep hill with a big load, when you start running down the other side you have obviously an increase in the generator pressure. That would be bad for an engine like this if we had not a good governor. I did not favor the high-speed governors, so we adopted the reducing valve which takes its supply from the boiler at 300 pounds pressure, the adjustment of a screw giving the engine a matter of about 60 to 65 pounds. It is really extraordinary how uniform the voltage remains on such a wide fluctuation, from 150 to 450 pounds boiler pressure. The little engine doing the job is on the seat beside the driver. The running cost of that lighting outfit is practically nothing. One very interesting point about it is that you can run with the lights full-on for three-quarters of an hour when the bus is standing without any additional water being fed into the boiler. The level drops about five inches in three-quarters of an hour. The voltage is 12. We use metallic filament lamps.

Now, gentlemen, I can only thank you very much for your exceedingly kind reception of my paper and I hope I have not taken up too much time. (Applause.)

## DISCUSSION.

PRESIDENT MARMON.—It is evident, after hearing this paper, that here in the States there is a whole lot about steam buses that we do not know. The paper is now open for discussion.

T. B. BROWNE.—Mr. President and gentlemen: I think I have already said what I have to say as regards which is the best, steam or petrol. Of course, we all know that Mr. Clarkson is the inventor of these steam buses. I think some of the advantages which he gives in his summary must be taken as advantages which existed some time ago. The petrol omnibus has improved tremendously, and I think some of these advantages really exist only in his mind on account of his great and natural parental love for his invention. (Laughter.) I refer to such points as smoothness of running and acceleration and the question of popularity; also the question of the drivers liking the buses. I think those points are really leveling up pretty much now. I think there is not so much difference between the steam and the petrol that way. In fact, I think the new petrol buses were certainly better than the steam buses until Mr. Clarkson produced his latest model. You might say that now the drivers do not care which they drive. They would like to drive the one where they get the most money.

THOMAS CLARKSON.—That is on the steam buses. (Laughter.)

T. B. BROWNE.—That accounts for the popularity, you see. I might perhaps refer again to the question of mileage lost. It seems to me that if you carry Mr. Clarkson's argument far enough, the buses should be running night and day, as you must not lose any time at all, either night or day.

A point which interested me very much is that of illumination. The

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London General Omnibus Company have been trying various devices and are now using a dynamo run by friction from the flywheel. They have a certain number being run by a rawhide wheel, some by rubber. I think they are favoring the rubber wheel. But the point is they have to carry accumulators, which I do not think are things to carry around on buses. It seems to me that the equivalent of Mr. Clarkson's system might be tried with an internal combustion engine—I have seen those very beautiful little electric sets and admired them very much—something might be brought about in the way of a two-stroke combustion motor using kerosene. It would require a great deal of experiment to get it right but it seems to me that would be the ideal motor. Something perhaps might be done in that way for illuminating the petrol omnibus.

THOMAS CLARKSON.—I will reply to one or two points Mr. Browne touched upon. Tests of acceleration have been made between the various types of motor buses, steam and petrol. The managing director of the London General Omnibus Company told me he had made independent tests of the various systems running in London, and said, "There is no doubt about it, the steam bus gets away faster than any of the others." That is a great traffic point in keeping the roads, when the bus can get up speed and be off without shaking up the people too violently.

In regard to popularity I will mention one thing. The secretary of the London Institution of Mechanical Engineers, who lives near the road where one service of these steam buses runs, told me he always makes it a practice to take a white bus because his experience is that he can allow four petrol buses to pass him and still be there first. (Laughter.)

As regards drivers and their preference, it is a very curious thing that we have a waiting list I do not know how long of drivers who want to drive steam buses. They make two dollars and a half a day, which is pretty good money for driving a bus; and they are able to do this on one shift. The practice of the London General Company is to have three drivers for two buses, two service men, and one relief man, who does half service on each. There are drawbacks to that service. The men are able easily to manage a whole day on a steam bus. They can have a day off any time they like by arrangement. There is no getting away from the fact that the drivers prefer the steam bus.

There is no object, of course, in trying to drive a bus twenty-four hours a day, as Mr. Browne suggests; as there is no traffic to be got during many hours of the twenty-four; we are after traffic receipts. The great traffic problem is to know when and where to run the bus, when to start in the morning, and when the rush traffic comes on and goes off. In certain parts of the city there is practically no traffic after eight o'clock at night.

As regards the light engine, Mr. Browne thinks something might be done to make a little self-contained kerosene motor dynamo on the lines of what we have done with steam. There are certain difficulties there: one of them is police limits as to weights. You would want a pretty hefty flywheel to give sufficient steadiness to get over the flickering of lights. When we began we made one-cylinder motors, single-acting, very

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much on the line of the little bicycle engine. But we could not get rid of the flickering of the lights, although you will remember, it being a steam motor, it had an impulse every revolution. We put on heavier flywheels but could not get rid of the flickering using a single-cylinder motor.

WILLIAM P. KENNEDY.—On the last subject which Mr. Clarkson took up, I would like to know what he thinks of the feasibility of putting a small floating storage battery, with probably a smaller kerosene engine than Mr. Browne has in mind, across the line and attempting to procure steadiness of light in that way, on a par somewhat with our railway system of lighting at the present time.

THOMAS CLARKSON.—Something might be done, of course. Our object is to get rid of the battery altogether, because it is a troublesome thing and expensive to maintain. Experience shows it is better not to put any sort of battery on the bus. They get shaken up so violently that the depreciation is abnormally heavy. One thing Mr. Browne omitted in speaking of what the London General Omnibus Company are doing. They are using a battery in conjunction with a dynamo, a system that we discarded.

HENRY SOUTHER.—May I ask what regulations the police place upon the driver of the steam bus, whether he must have a license?

THOMAS CLARKSON.—Yes.

HENRY SOUTHER.—A license requiring more education than for the gasoline bus driver?

THOMAS CLARKSON.—No, sir. All the drivers come in the same category as regards a license from Scotland Yard. Before a license is granted to a driver his antecedents are inquired into, particularly as to whether he has ever been in jail. If he is pretty well behaved, he has to undergo a test for fitness, a special test before one of the examiners, in handling and maneuvering a bus. A driver is licensed to drive a particular make of bus; he is not licensed to drive any bus in the Metropolitan area. If he is licensed to drive a steam bus he must have another test and license before he is permitted to drive a petrol bus, or vice versa.

A. J. SLADE.—In regard to the statement "Buses withdrawn from the service for annual overhaul, 1.844 per cent.," that means withdrawal from service about six days per year per bus. I understood Mr. Clarkson to say that when the buses were overhauled they were brought right up to date and improvements that may have been brought out in the past year are incorporated. Do I understand correctly that all that can be done in six days? Furthermore, as regards the ordinary incidental repairs that may be required from day to day and week to week, are they done at night or are the buses withdrawn from service for that purpose?

THOMAS CLARKSON.—The whole mileage is included in the schedule given—1.844 is the whole time they are taken off service for their annual overhaul, as required by the police regulations. The time varies a little. Sometimes the work can be done in five days, sometimes it is six or eight or nine in exceptional cases. What we arrange to do and what is allowed by the police is to have all the material ready. It may be a new engine.

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We do not bother to take an engine off and overhaul it and put it back in the same chassis. We strip the chassis right down and have new parts ready to put on it. An overhauled engine is put on, and maybe a new or overhauled generator and condenser. These several units go through a regular system of overhaul in the shops, to be in readiness for another chassis overhaul. In that way only are we able to keep the buses in service less that percentage.

C. H. TAYLOR.—I would like to ask Mr. Clarkson as to the probable or approximate cost of these annual repairs. I know that his depreciation charge is about 16 or 17 per cent., but would like to find out, in addition to that, what the annual repair cost is, approximately.

THOMAS CLARKSON.—The cost of the body overhaul, including repainting, is about twenty-five pounds. The chassis overhaul cost varies. If the chassis has had bad collision, it may be sixty or seventy pounds, sometimes more. That may give an approximate idea. Usually a chassis can be done for about forty or fifty pounds; I am not including the bringing uptodate, that is a separate account.

## WORM GEARS

D. FITZPATRICK.—I would like to endorse Mr. Clarkson's remarks as to giving preference to riding in the steam buses. I would willingly let three General buses pass me to get one of Mr. Clarkson's. In going from Shepherds Bush down to Oxford Circus I would get there first, I know.

I would like to ask Mr. Clarkson if he has any data as to the life of one of the worm gears after running for years. There is a great deal of doubt in this country about it.

THOMAS CLARKSON.—The life of a worm gear is, of course, divided between the worm and the gear wheel. The ring, I believe, we have had running two seasons; that is to say practically 60,000 miles. I know that some have done 70,000 miles. The worm will normally outlast two or three bronze wheels. But it is very essential to have the gear accurately mounted, so that the centers are correct and the endthrust taken up properly; otherwise the life of the worm gear is very much less. We have lately installed a plant for making these gears. The worm is ground to a proper angle and to the proper helix after going through the hardening operation. Only in that way can we get it properly centered.

T. C. PULLINGER.—May I ask Mr. Clarkson at what point in the life of the worm gear it attains its maximum efficiency and at what point in its life he considers it has so low an efficiency that it will pay him to take it out and put in a new one?

THOMAS CLARKSON.—Increased fuel consumption would result as soon as the worm gear became less efficient. If there is any particular change in the formation of the teeth, the worm gear is very easily inspected through a cover on the gear case. Any alteration in the condition of the gear can be noted periodically. If any deformation in the worm or gear teeth or in the condition of their surfaces is noted, we should expect a loss of efficiency.

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STEAM BUSES IN AMERICA

PRESIDENT MARMON.—Mr. Birdsall in years past burned his fingers on the pipes of the steam car a good many times. I would like to have him close this discussion.

E. T. BIRDSALL.—Mr. Chairman, I thought I was going to escape. (Laughter.) For the benefit of our British friends I would say that I built a near-copy of the Thorneycroft lorry for six-tons capacity. The principal trouble we had here was to keep the engine connected to the generator. (Laughter.) The Cook Locomotive Works imported ten Thorneycrofts, and it was a great satisfaction to me that they had the same identical trouble. The main difficulty was the condition of our streets. If he knew the condition of the asphalt pavements in New York, I think even Mr. Clarkson would hesitate to introduce a bus line in New York. The depreciation would be enormous. In fact, the difficulties of depreciation of taxicabs due to their bad condition has, I believe, been the cause of the very poor financial condition of the taxicab companies in New York.

I would like to ask Mr. Clarkson one question: If there were no police regulations in regard to noise, would he continue to use the worm drive?

THOMAS CLARKSON.—First, as regards running buses in New York, I would be only too glad to have a chance of running a fleet there. I think something better than the present service could be given to the public. There are many routes there which I believe could be run very profitably. It made my mouth water the other day when I was in New York to see that ten cents is the usual fare on the buses. (Laughter.) We have to carry an adult person the best part of a mile for one cent.

I have no reason at present to be "out of friends" with the worm gear. We have passed it through some very severe tests. I took one of our chassis year before last, put a platform on it, two or three tents and some other equipment, and went out into north Wales with six others. We used this thing as a touring caravan. We went around north Wales a good deal, on pretty heavy country roads, some of the grades being very severe. The worm gear stood up all right. The last day's journey, running home, was two hundred and twenty miles, a pretty good run for a heavy bus chassis with the load it had on. I think the worm gear is all right if properly made; but that implies, as I have already said, accuracy of alignment and proper taking of the thrust. We have found it desirable to put in heavier ball bearings and thrust washers than we did formerly. We had some of them crushed by the extremely severe action of braking and driving. But I think we have not had any cases of failure of worm drive except where the lubrication has failed. Sometimes there have been pretty violent collisions which knocked holes in the differential case, the oil running out and the man not noticing it, and the worm becoming dry and injured. I think the worm gear is all right.

PRESIDENT MARMON.—The Transactions of the Society are going to be very much poorer because we have not all day to discuss this matter.

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# CALCULATING DEPRECIATION OF COMMERCIAL AUTOMOBILES

By CHAS. WHEELER, Member of Council I. A. E.

Depreciation has been defined as the diminution which takes place in the value of a wasting asset in spite of the amount expended on it in repairs, and there is no doubt that in assessing the diminution in value of commercial vehicles something more than the application of definite accountancy principles is necessary. This is probably true as applied to all factory accounting, which in effect is *dissection* as opposed to *combination*, the usual operation of commercial accounting.

If exception be taken to this short paper on the ground that the subject treated is more of a commercial than of an engineering character, I would point out that the scientific keeping of accounts connected with automobile production and the running of automobiles is of vast importance, and necessitates expert engineering advice in nearly all departments. In fact, the engineering head must not only know what cost he is "up against" on the score of depreciation, but he must have a big voice in the determination of the governing factors.

The first factor to be considered is the estimated "working-life" of the automobile, and this depends very largely on the particular circumstances in which the vehicle is used. Thus a Maudslay motor bus runs some 700 miles per week, while a Maudslay stores van averages say 140 miles per week. Obviously, other things being equal, the length of the "working-life" must be considerably in favor of the stores van. The "working-life" also depends upon the quality of the vehicle, i.e., quality in design and manufacture, and is thus closely connected with the initial cost. The "working-life" further depends upon the condition in which the vehicle is maintained, and this in turn depends upon the driving and supervision, and the amount spent on renewals.

Having decided upon an estimated "working-life" $L$, the next step is to consider by what method the initial cost should be spread over the period decided upon—in other words how the depreciation should be written off year by year. Three methods at least warrant consideration, namely:

(1) To divide the capital outlay $C$, by the number of years at which the "working-life" $L$, is estimated and charge the quotient against each year's working costs.

(2) In the first year to write off a high percentage of the cost; in the second and succeeding years to write off the same percentage on the diminished value, that is, the balance left after deducting the previous year's depreciation.

(3) To divide the capital outlay $C$, *less residual value*, $R$, (that is, the estimated value of the vehicle at the end of its "working-life") by the number of years, etc.

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In each method, renewals and repairs, as they occur, are charged against "general running expenses."

The first method cannot of course be recommended where any degree of accuracy is required.

The second method is perhaps financially the soundest if it be desired to ascertain from one's books the actual realizable value of the vehicle at any moment. Although this method gives a fairly true result in the end, it has the objection that in its earlier years the cost of the service is overloaded.

The third method, expressed by the formula $\frac{C-R}{L}$, where $C$ = capital outlay, $R$ = residual value, and $L$ = the estimated years of life, is that recommended as being the most practical and accurate method. The only observation necessary on this method is one dealing with the reconsideration of $L$ at a later period. When the life of a vehicle is reconsidered, the *unexpired capital outlay* should be taken as the basis for the revised charge for depreciation. Thus suppose $\frac{C-R}{L} = \frac{500-50}{5}$, the annual depreciation being £90; by the end of two years the capital outlay would have been written down to £320. If the estimate of life be then revised and extended to seven years in all, with five more to run, then $\frac{C-R}{L} = \frac{320-50}{5} = £54$ annual depreciation.

Obsolescence is a factor which has to be considered, as it is by no means improbable that some combination of circumstances may render it desirable to dispose of a particular vehicle before it is really worn out. From a strict accounting point of view obsolescence may not be depreciation, but the factor is at least of sufficient importance to "round up" any percentage that may be determined by other considerations, and if, in the future, by perfecting the machines, their ordinary working life can be reckoned as longer than it is at present, obsolescence will become of more importance, for a machine which is still quite efficient mechanically may be rendered uneconomical by the introduction of improved types. When such time arrives it may be prudent to make provision under this head, which while not strictly proper to depreciation may very conveniently be connoted.

There remains one other detail for consideration, namely, the treatment of small additions to plant. The effective life of the additions may or may not be co-terminous with that of the vehicle, and any attempt to bring their depreciation within the scheme for the depreciation of the vehicle itself would cause complications which it would not be worth while to incur. The practice recommended is to regard such small additions as chargeable to maintenance, which, in effect, means writing them off at 100 per cent. in their year of purchase.

(A rising vote of thanks was given Mr. Wheeler for presenting the paper).

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# THE MEASUREMENT OF HORSEPOWER

By Prof. W. Morgan, B. Sc., and E. B. Wood, M. A.

The authors feel they need offer no apology for dealing with this question, as the importance of B. H. P. testing must be apparent to all, both in the case of the pass tests of the finished product and for the trying-out of improvements in design or new types of engines. The errors of measurement in the case of the former should not exceed 5 per cent. and in the latter 2 per cent. or less. In both cases it is essentially the torque curve that it is desirable to examine and in any form of brake in which the torque is proportional to the square of the speed, an error in counting is increased.

From time to time power results are published which are so superlative and so far beyond anything in the authors' experience that they are inclined to cast doubt, not on the good faith of those responsible, but on the accuracy of the apparatus employed.

In comparing results obtained on engines of different size it is advisable to reduce the figures to brake mean effective pressure and piston speed. Some results taken from the technical press are as follows:

| M. E. P. lb. per sq. in. | Piston speed ft.-min |
|---|---|
| 130 | 2,000 |
| 127 | 2,000 |
| 115 | 2,760 |

It is obvious that with high-class automobile engines of the ordinary four-cycle type having compression ratios not exceeding about 5, the maximum power available at any speed is directly proportional to the amount of oxygen the engine can burn at that speed, rather than in any way dependent on the amount of fuel, provided there is sufficient fuel to completely utilize the oxygen.

Consequently the maximum horsepower is determined by piston displacement and volumetric efficiency. Tests in which the air has been measured, such as those by Dr. Watson, in London, and Dr. Riedler, in Berlin, show that 2 cubic feet per B. H. P. is a fair figure.

So it may be taken that Max. B. H. P. $= \frac{D^2 SN \times R.P.M.}{9{,}500}$, where $D$ and $S$ are bore and stroke in inches respectively and $N$ the number of cylinders of a four-cycle engine, a volumetric efficiency of about 92 per cent. being assumed. This gives an equivalent mean effective pressure on the brake-horsepower of 105 lb. per square inch. Any published figures which exceed this, especially at very high piston speeds, should be looked upon with suspicion.

The difference between this figure of 105 lb. per square inch as the probable mean effective pressure and the figures quoted above raise

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doubts as to the reliability of the brake used in measuring the horsepower of these engines. Generally in such reported performances no information is given about the dynamometer employed; but the high engine speeds attained suggest that some form of fan brake has been used. On account of its adaptability, cheapness and simplicity this brake is frequently used for high-speed work, and for reasons of safety is generally placed near

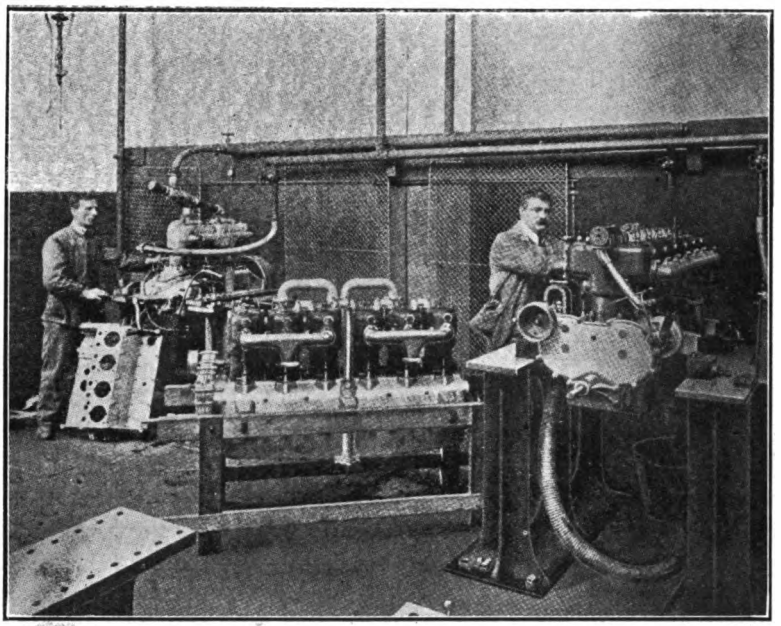

Fig. 1.

a wall or in an alcove, or protected by a casing. See Figs. 1, 2 and 3, which give examples of the conditions under which the fan brake is actually used. As the horsepower absorbed by a fan brake is estimated from a formula it is natural to suspect that environment must play an important part in the conditions of power absorption, and that the performance of a fan may vary with its position. This has been the experience of the authors, and they were inclined to write down the fan brake as hopeless. Its great convenience for various forms of test prompted them to investigate the limits within which the fan brake is reliable and the experiments described below were carried out accordingly.*

It is now proposed to refer briefly to the merits and demerits of well known types of absorption dynamometers. Before doing so it would be well to state the great advantages obtained by mounting the whole engine test bed on springs (see Figs. 4 and 5) instead of having it rigidly

*The authors wish to state that they were much assisted in the work by Mr. D. E. Gough.

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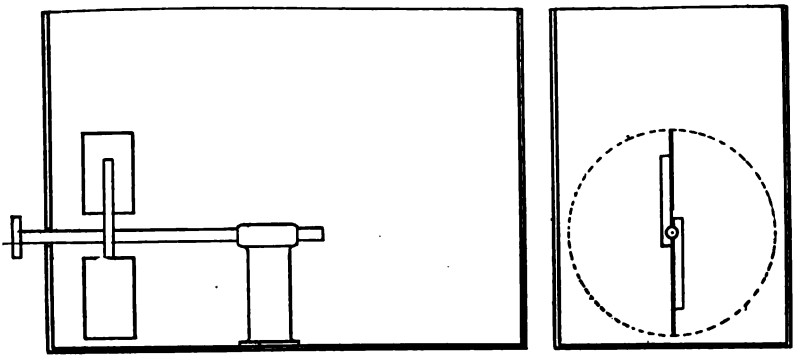

Fig. 2.

fixed to the floor. These springs were first used to minimize the amount of vibration transmitted to the floor; subsequently it was found that they presented such advantages for high-speed work that they were worth retaining on that account alone. A modern aluminum base chamber is frequently so flexible that considerable distortion must occur at high

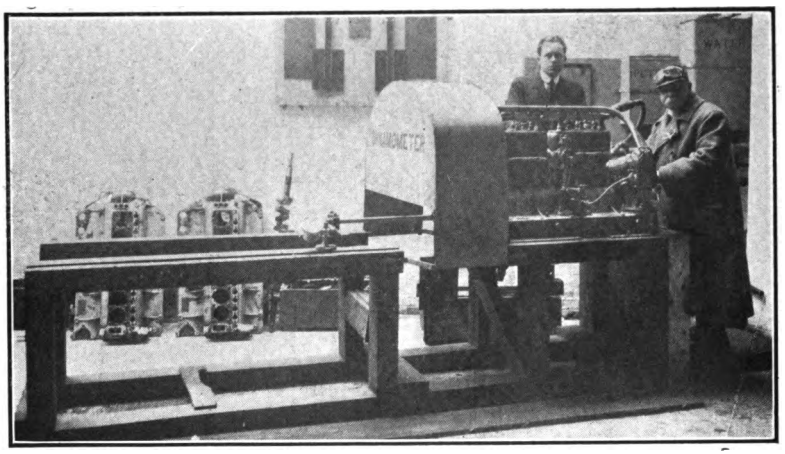

Fig. 3.

speeds, when bolted directly to a heavy cast iron bed, cases being known in which the engine brackets have broken from this cause. These remarks are especially applicable to aeroplane engines.

*Solid Friction* brakes, whose main characteristic is that the torque is to a great extent independent of the speed.

The ordinary rope brake may be taken as an example, being cheap in first cost and on the whole fairly accurate, but it requires a special internally-cooled flywheel and rather troublesome water outlet connections. It takes considerable skill in handling and at the best is liable to hunt, especially

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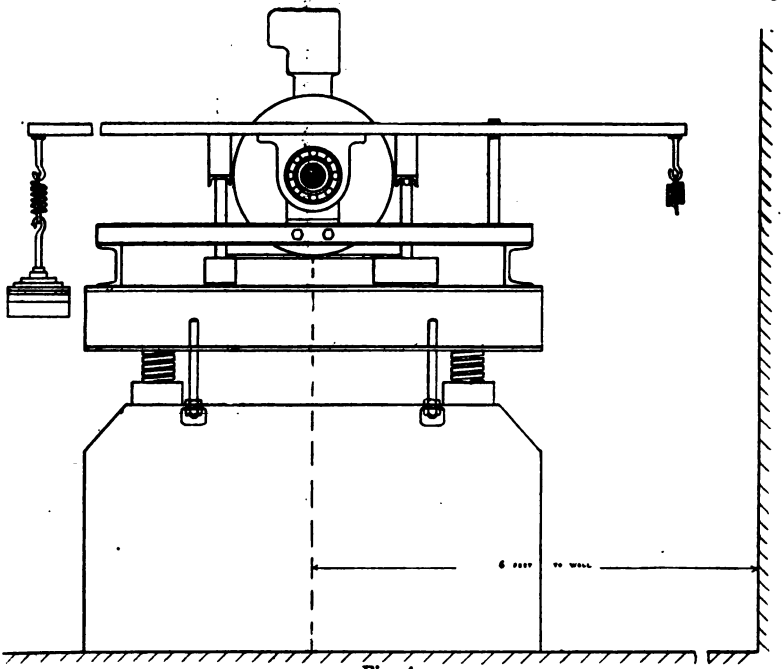

Fig. 4.

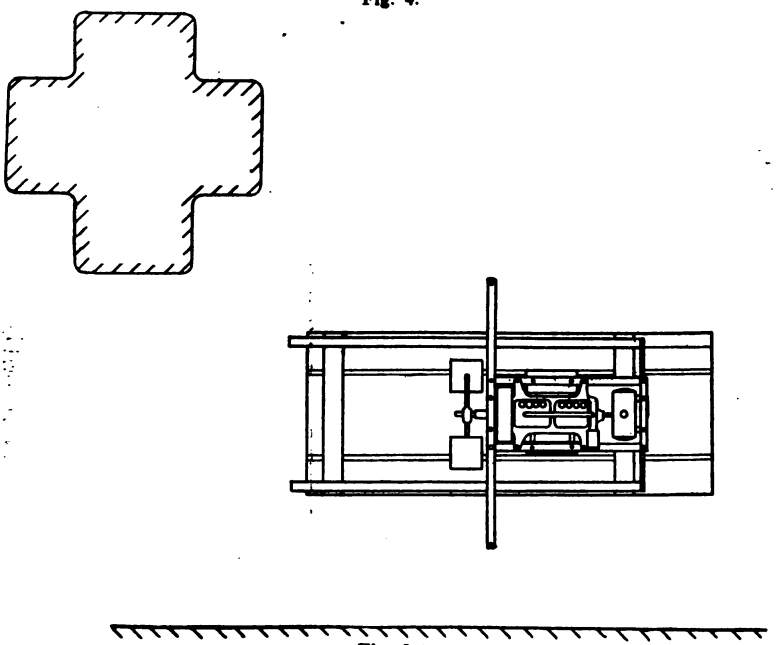

Fig. 5.

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with a modern engine having a flat torque curve, as in Fig. 6. To take an example, suppose the engine is running at 1,100 revolutions per minute with a torque of 156 lb. at 1 foot; if for any reason the engine torque decreases slightly, say 4 per cent., the engine will stop unless the brake is slackened to a torque of 150 lb. before the engine slows to 700 revolutions per minute, in which case the engine may speed up to 2,100 revolutions on recovering its full torque. In the case of brakes in which the torque varies as the square of the speed, the effect of a similar decrease of engine torque is only to reduce the speed from 1,100 to 1,078 revolutions per minute.

*Electrical Brakes,* Dynamo Type.—Torque varies as speed. In general

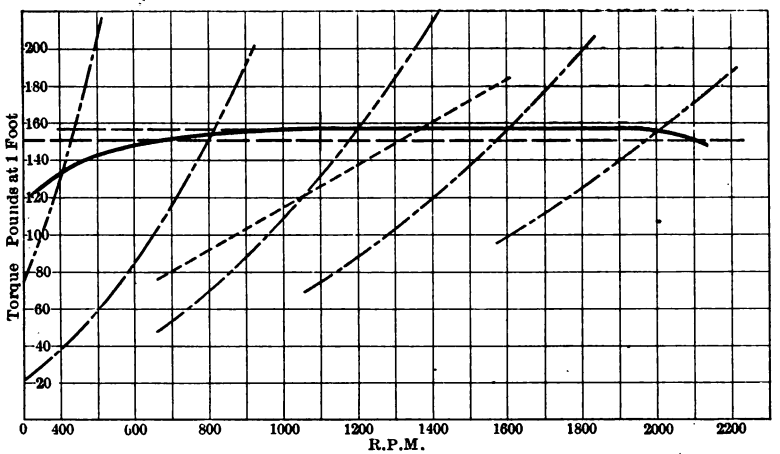


**Fig. 6.**

these are expensive in first cost, being specially designed with a small diameter armature to allow of high peripheral speeds, and, as a rule, they are mounted on a rigid bed and connected to the engine by some form of flexible coupling. They must be large enough to absorb the maximum power required. They certainly have the advantage of being able to drive the engine if necessary, but a much smaller and cheaper motor will do this satisfactorily. If the power is measured electrically, it involves a calibration of the apparatus, which calibration may easily be affected by external influences. A better method is that in which the field magnets are pivoted and the torque measured by hanging weights on an arm. This is not, as a rule, strictly accurate as it neglects windage and bearing friction, when absorbing power, and includes them when giving power. The windage, at any rate, is quite appreciable at high speeds.

Another form is the *eddy current brake,* which consists of one or more copper disks rotating between the poles of the pivoted electromagnets, the load being varied by means of the excitation. This is cheaper than the above type and requires no electrical connections with the rotating parts, and is not so suited to low-speed work as the two previous types. The copper discs are apt to overheat and warp in spite of means provided for

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ventilation and the windage of these ventilators must be reckoned with.

*The Water Brake* is very compact for the power it absorbs and has very few working parts to wear and get out of order, but is expensive and requires a flexible coupling. It is reported to be none too sensitive, but the authors have had no personal experience with this type.

*The Fan Brake* is exceedingly cheap and easy to fit direct and enables one man to take charge of the engine, as it keeps a very steady speed and prevents racing. Its defects are that it is unsuitable for low speeds on

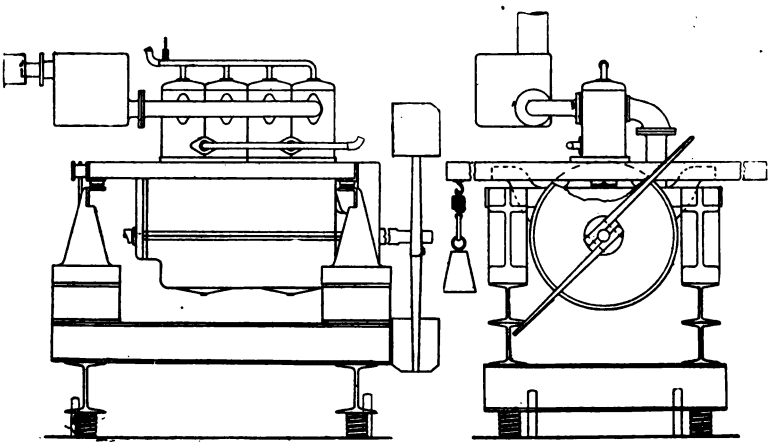

Fig. 7.

account of its bulk, it is noisy and the engine has to be stopped and the blades altered if it is desired to take full load tests at different speeds or different loads at the same speed. Its great disadvantage is that the horsepower reading is dependant on a formula in which the constant is very susceptible to changes of air pressure and temperature and to environment.

Owing to its many advantages, particularly with respect to aeroplane engines, which are so lightly built as not to be adapted to rigid mounting and coupling up, it was decided to make some tests as to the limitations of this particular form of brake. The method employed was that of measuring the counter torque of the engine, and the apparatus used is shown diagrammatically in Figs. 4 and 5. A hollow bracket mounted on the "dead" frame carries the inner race of a large ball bearing; an extension of the crankshaft, concentric with the ball race, passing through but not touching the bracket. This method of mounting is not essential (another arrangement is shown in Fig. 7), but in the case of driving the engine by means of an electric motor it removes the disturbing influence of the universal joint. The outer ball race fits in a housing which supports a transverse member, which in the case of the flywheel end also forms the arm from which the weights are suspended. The petrol tank is mounted on the "live" frame and care is taken that the water connections cause no restraint. It is essential that the exhaust

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should discharge parallel to the axis of the engine and the pipe should be in no way constrained, but should project some distance into a larger pipe. Counterweights are bolted to the "live" frame in order to bring the center of gravity of the engine and frame in line with, but very slightly below, the axis of the supporting bearings. The sensitiveness of the apparatus mainly depends on the accuracy of this balancing. With the engine running, the bed shown in Fig. 4 would easily turn to ½ oz. at a radius of 35

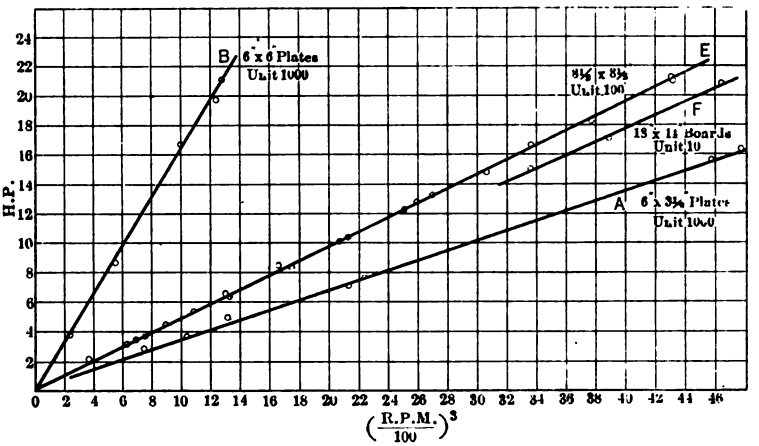


Fig. 8.

inches, this being equivalent to 0.017 horsepower at 1,000 revolutions per minute.

The object of these experiments was:

1. To examine the reliability of the formula

$$HP = CN^3$$

where

$N$ = revolutions per minute.

2. To obtain, if possible, an expression for $C$ in terms of fan dimensions.

3. To note the effect of adjacent objects.

4. To observe the effect of air currents.

### THE RELIABILITY OF THE FORMULA $HP = CN^3$

Experiments were conducted with fans of various areas at varying distances from the center of rotation. A selected fan was run in a given position at as wide a range of speed as possible. Readings of horsepower consumed by this fan were taken at different speeds. This experimentally determined horsepower was for each case plotted against $N^3$ (Fig. 8). In each case the resulting graph is a straight line through the origin, that is

$$HP = CN^3$$

The value of $C$ for each fan is given by the corresponding graph,

$$C = \tan \Theta$$

where $\Theta$ is the angle of inclination of the graph and the respective perpendicular and base lines are read to scale.

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## TABLE I

| Series | Plates D×C | H. P. at 1,000 R.P.M. | $\frac{C^1}{A}$ | Radius of Centre of Gravity $l$ | Radius of Third Moment $-\sqrt{\left(l^2+\frac{D^2}{4}\right)}$ | Per Cent Error on Calculated Results Below | Above |
|---|---|---|---|---|---|---|---|
| A.... | 6″x3½″ | 0.353 | 8.42 | 6.27″ | 6.76″ | 13.7 | .... |
| | | 0.399 | 9.5 | 6.65″ | 7.12″ | 14.5 | .... |
| | | 0.662 | 15.75 | 8.15″ | 8.54″ | 20.6 | .... |
| | | 0.844 | 20.1 | 8.9″ | 9.22″ | 18.3 | .... |
| B.... | 6″x6″ | 0.39 | 5.42 | 5.03″ | 5.58″ | .... | 6.2 |
| | | 0.774 | 10.76 | 6.53″ | 6.96″ | .... | 4.5 |
| | | 1.495 | 20.8 | 8.53″ | 8.87″ | 4.5 | .... |
| | | 2.54 | 36.2 | 10.53″ | 10.80″ | 7.6 | .... |
| | | 3.59 | 49.8 | 12.03″ | 12.27″ | 13.0 | .... |
| B'... | ..... | 1.625 | 22.6 | 9.03″ | 9.36″ | .... | .... |
| | | 2.370 | 32.9 | 10.53″ | 10.80″ | .... | .... |
| | | 3.36 | 46.6 | 12.03″ | 12.27″ | .... | .... |
| C.... | 6″x8½″ | 0.617 | 6.05 | 5.375″ | 5.887″ | 24.5 | .... |
| | | 0.728 | 7.06 | 5.75″ | 6.225″ | 6.2 | .... |
| | | 1.09 | 10.7 | 6.5″ | 6.93″ | .... | 3.0 |
| | | 1.495 | 14.65 | 7.25″ | 7.64″ | .... | 5.0 |
| | | 1.860 | 18.25 | 8.0″ | 8.36″ | 0 | 0 |
| D.... | 8½″x6″ | 0.79 | 7.75 | 5.375″ | 6.316″ | 1.4 | .... |
| | | 0.895 | 8.77 | 5.75″ | 6.652″ | 1.8 | .... |
| | | 0.920 | 9.02 | | | | |
| | | 1.235 | 12.1 | 6.5″ | 7.32″ | 1.0 | .... |
| | | 1.708 | 16.75 | 7.25″ | 8.00″ | .... | 5.0 |
| | | 2.17 | 21.25 | 8.0″ | 8.69″ | .... | 3.8 |
| E.... | 8½″x8½″ | 1.56 | 10.83 | 6.283″ | 7.12″ | 4.0 | .... |
| | | 2.717 | 18.85 | 7.785″ | 8.48″ | 1.0 | .... |
| | | 3.88 | 25.0 | 8.785″ | 9.416″ | 4.0 | .... |
| | | 5.013 | 34.8 | 9.785″ | 10.35″ | .... | 0.6 |
| | | 6.48 | 45.0 | 10.785″ | 11.29″ | .... | .... |
| | | 10.30 | 71.7 | 13.285″ | 13.71″ | .... | .... |
| E'... | ..... | 5.13 | 35.6 | 9.785″ | 10.35″ | .... | .... |
| | | 11.20 | 77.8 | 13.285″ | 13.71″ | 3.3 | .... |
| F.... | 28″x14″ | 190.5 | 243.0 | 16.75″ | 19.97″ | 2.0 | .... |
| | 26″x16″ | 167.0 | 201.0 | 15.75″ | | | |
| | 26″x14″ | 149.0 | 204.5 | 15.75″ | 18.73″ | 0.25 | .... |
| | 26″x12″ | 119.0 | 191.0 | 15.75″ | | | |
| | 24″x14″ | 114.8 | 170.8 | 14.75″ | 17.46″ | 0 | 2.8 |
| | 24″x12″ | 95.6 | 166.0 | 14.75″ | | | 0 |
| | 22″x12″ | 70.0 | 132.5 | 13.75″ | 16.21″ | 0.4 | .... |
| | 21″x14″ | 69.5 | 118.0 | 13.25″ | 15.60″ | 0.3 | .... |
| | 20″x12″ | 52.7 | 110.0 | 12.75″ | 14.95″ | .... | 5.0 |
| | 18″x14″ | 40.5 | 80.3 | 11.75″ | 13.70″ | 0 | 0 |
| | 18″x12″ | 34.2 | 79.2 | 11.75″ | | | |
| | 16″x12″ | 22.0 | 57.3 | 10.75″ | 12.48″ | 5.0 | .... |

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**TABLE I—Continued**

| Series | Plates D ⟩ C | H. P. at 1,000 R.P.M. | $\frac{C^1}{A}$ | Radius of Centre of Gravity $l$ | Radius of Third Moment $-\sqrt[3]{l\left(l^2+\frac{D^2}{4}\right)}$ | Per Cent Error on Calculated Results Below Above |
|---|---|---|---|---|---|---|
| G1... | 6″x6″ | 8.5 | 118.0 | 17.7″ | 17.86″ | Poppe formula |
| | | 11.1 | 154.0 | 19.7″ | 18.85″ | |
| | | 14.3 | 198.0 | 21.7″ | 21.83″ | |
| | | 18.0 | 250.0 | 23.6″ | 23.73″ | |
| | | 22.2 | 308.0 | 25.6″ | 25.71″ | |
| G2... | 8½″x8½″ | 20.2 | 140.0 | 17.7″ | 18.02″ | |
| | | 26.1 | 181.0 | 19.7″ | 20.0″ | |
| | | 33.0 | 230.0 | 21.7″ | 21.97″ | |
| | | 41.2 | 286.0 | 23.6″ | 23.85″ | |
| | | 50.5 | 350.0 | 25.6″ | 25.78″ | |
| G3... | 12″x12″ | 50.5 | 175.0 | 17.7″ | 18.37″ | |
| | | 64.3 | 223.0 | 19.7″ | 20.29″ | |
| | | 80.2 | 278.0 | 21.7″ | 22.24″ | |
| | | 98.7 | 343.0 | 23.6″ | 24.09″ | |
| | | 119.5 | 415.0 | 25.6″ | 26.06″ | |

For any given fan at a given distance from the axis of rotation, the range of speed was usually two to one; over the whole fans employed the speed varied from 350 to 3,500 revolutions per minute. In no case was there any suggestion that the formula $HP = CN^3$ failed to hold good.

It should be noticed that as each series of observations was taken continuously, atmospheric conditions did not change appreciably during any one series of tests. Also the relative position of surrounding objects remained unchanged. The experimental value of $C$ thus obtained for a given fan was in all cases obtained as the result of a number of observations varying from 3 to 25. It is important to remember this, as afterwards in an attempt to find some simple expression for $C$ these experimental constants are plotted against other quantities. In such case the plotted points may reasonably be expected to fall in a smooth curve, and any raggedness of arrangement must be put down to atmosphere or environment effects.

### VALUE OF THE CONSTANT $C$

It will be assumed, for the moment, that atmospheric conditions are constant, and that the fans are fairly removed from surrounding objects.

It has been shown that over very wide ranges of speed

$$HP = CN^3 \qquad \text{I}$$

$C$ may be expressed in terms of other quantities, as

$$HP = 8\pi^3 a A R^3 N^3 \qquad \text{II}$$

where

$a$ = resistance constant of air per unit area
$A$ = area of plates
$R$ = radius of center of pressure

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equating I and II

$$CN^3 = 8\pi^2 a A R^2 N^2$$

$$C = 8\pi^2 a A R^2$$

In this case, for all fans of equal radii of pressure centers, $C$ would be directly proportional to $A$; the expression is better written

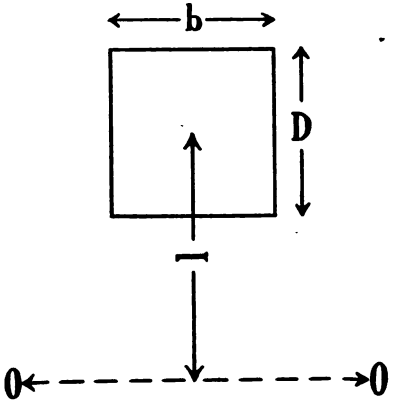
$$\frac{C}{A} = 8\pi^2 a R^2$$

$$= KR^2$$

where

$$K = 8\pi^2 a$$

It is now necessary to find a value for $R$. If the air impinged normally on the plates, the radius of the center of pressure would be as determined below




Let $OO$ be the axis of rotation.

$l$ = the radius of center of gravity.

$D$ = the depth of plate

$b$ = the breadth of plate.

Then the $HP$ absorbed by any element of surface $b.dx$ is

$$HP = KN^3 b.dx.x^2$$

where $x$ is the distance of any element $b.dx$ from $OO$.

$HP$ absorbed by whole fan

$$= KN^3 b \int_{e-\frac{D}{2}}^{e+\frac{D}{2}} x^2.dx.$$

$$= KN^3 bDl\left(l^2 + \frac{D^2}{4}\right)$$

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but from equation II $HP=KN^3AR^3$

$$\therefore R^3 = l\left(r^2+\frac{D^2}{4}\right)$$

$$\therefore R = \sqrt[3]{l\left(r^2+\frac{D^2}{4}\right)}$$

$$\therefore \frac{C}{A} = Kl\left(r^2+\frac{D^2}{4}\right) \qquad \text{III}$$

This, then, would be the expected value of $R$ if the air impinged normally on the fan plates. This, however, does not occur, for the air flows radially outwards through the fan and some displacement of the center of pressure may occur. It now remains to be seen to what extent this formula III is correct.

If $\frac{C}{A} = KR^3$

where

$$R = \sqrt[3]{l\left(r^2+\frac{D^2}{4}\right)}$$

Then

$$\log\frac{C}{A} = 3\log R + \log K$$

which is of the form

$$y = 3x + C$$

and shows that the graph obtained by plotting $\log\frac{C}{A}$ against $\log R$ is a straight line.

These experimental quantities $\log\frac{C}{A}$ obtained from a series of fans have been plotted against $\log\sqrt[3]{l\left(r^2+\frac{D^2}{4}\right)}$ in Fig. 9.

In the examination given above the possible effect of the arm carrying the fan has been ignored. Readings were taken to measure this effect.

**TABLE II**

**H.P. Absorbed by Fan Arm**

| Radius | Width | Depth | Speed | H. P. | Const. |
|---|---|---|---|---|---|
| 12″ | 1″ | 0.75″ | 1,800 | 1.02 | 0.175 |
| 10″ | 1″ | 0.75″ | 3,500 | 3.29 | 0.0736 |
| 8″ | 1″ | 0.75″ | 3,760 | 1.8 | 0.0338 |

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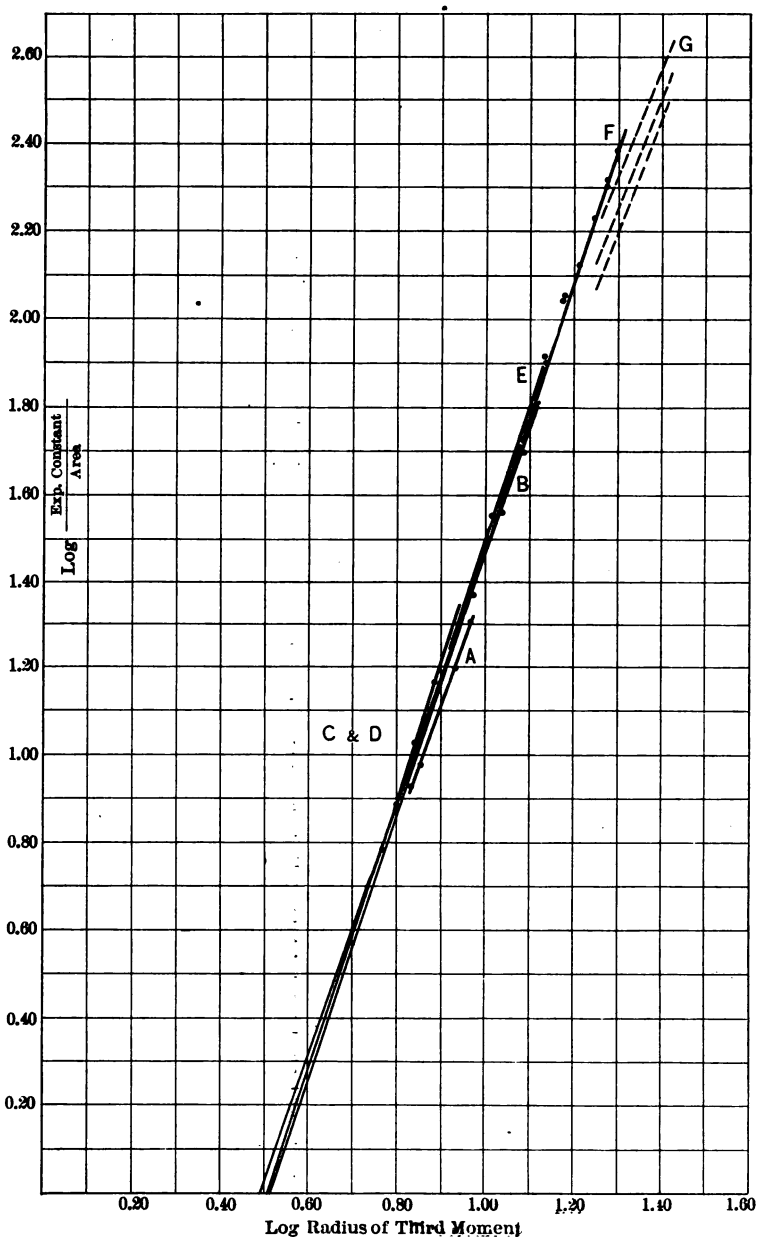


Fig. 9.

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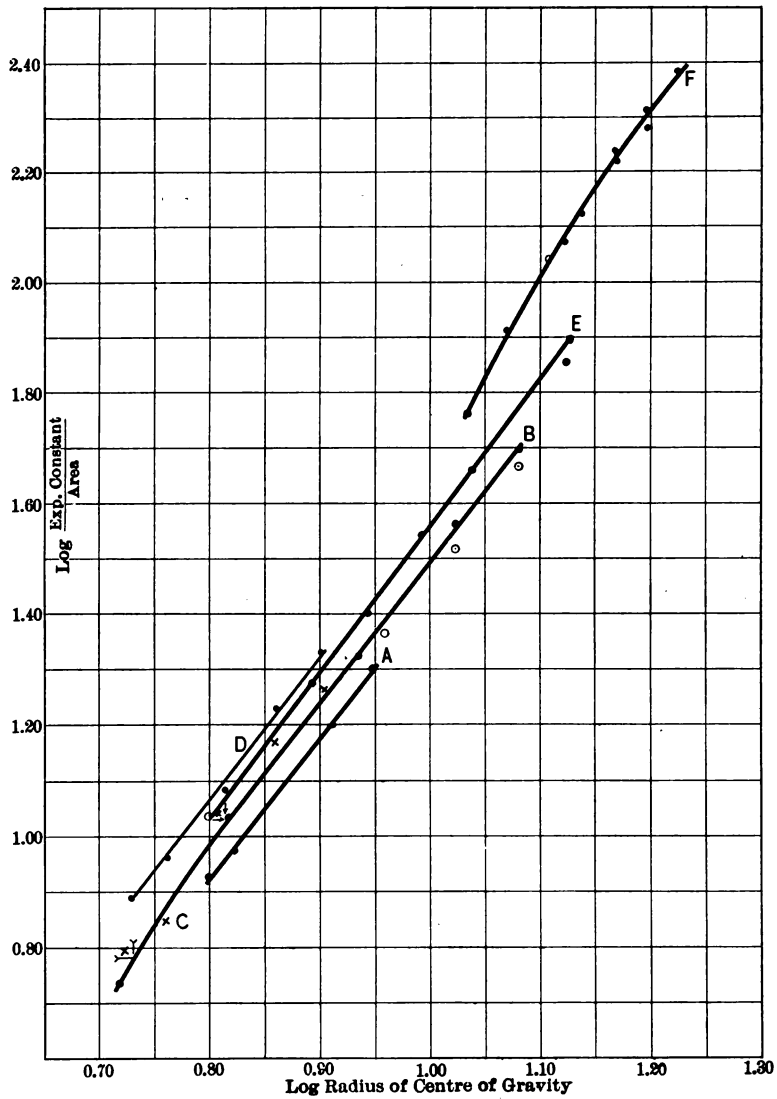


Fig. 10.

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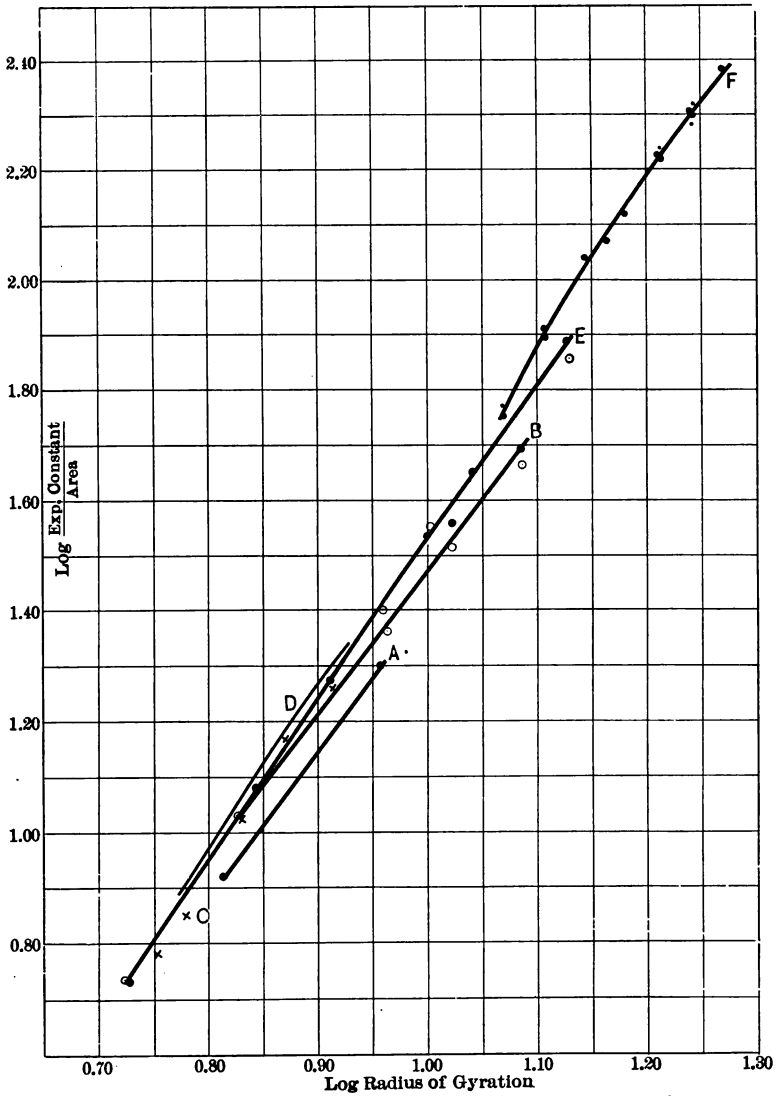


Fig. 11.

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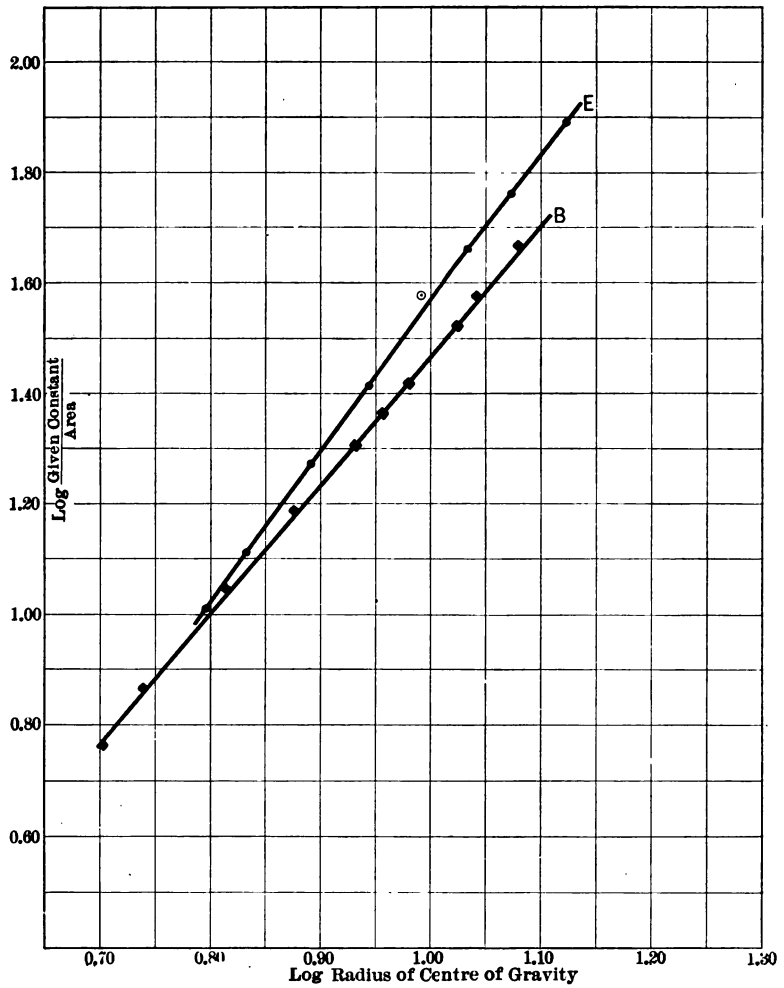


Fig. 12.

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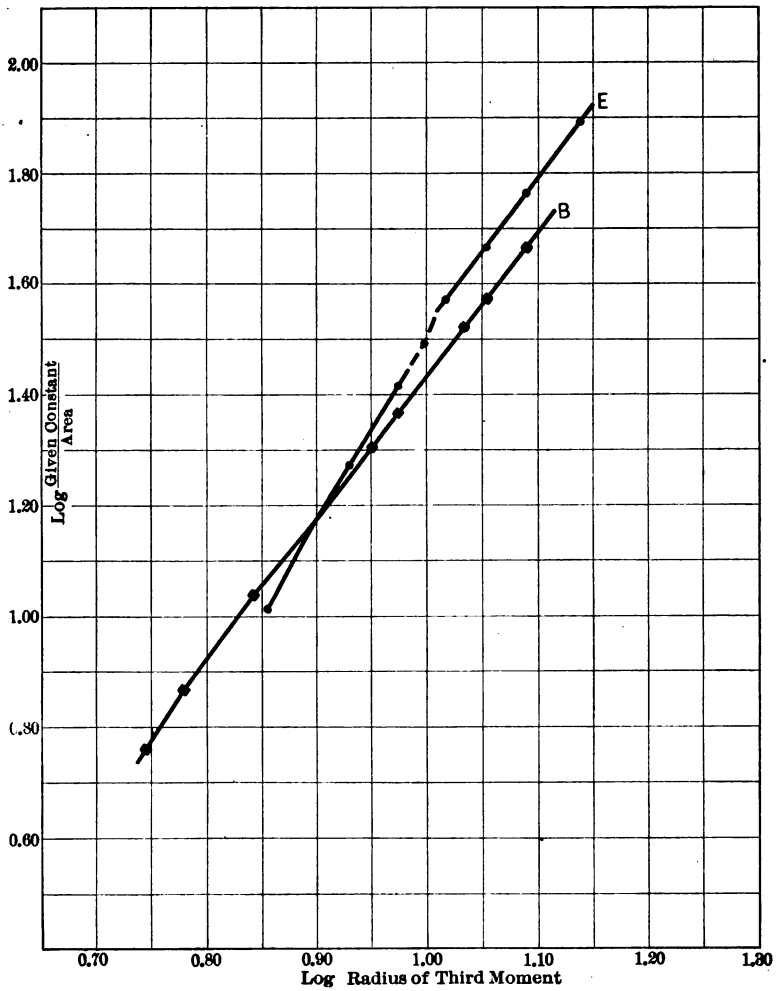


Fig. 13.

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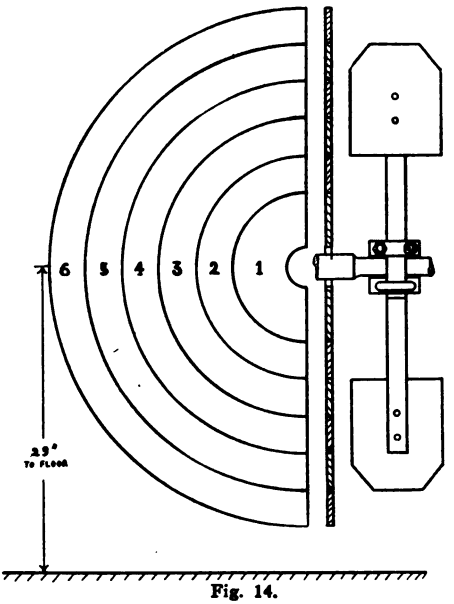


Fig. 14.

Only in the case of the smaller plates was the arm effect appreciable, and the *HP* results of these plates were corrected for this effect.

The constants given by a large number of fans have been considered. See Table I. Groups A, B, C, D, E have been obtained from different plates by altering the radii of the C. G. Group F contains the results obtained from a large assortment of plates, but with little variation of the radius of C. G. for each plate. In every case, however, the value of $\frac{C^3}{A}$ has been calculated from a series of observations.

The graphs plotted in Fig. 9 may fairly be taken as straight lines of the form $y = mx + c$ and with the exception of graph of A appear to lie well about some common axis.

Examining each graph separately it is at once seen that no graphs obey the $\frac{C}{A} = KR^3$ formula exactly.

Indeed, this is to be expected, and it is clear that no simple general expression for $\frac{C}{A}$ may be obtained.

If, however, a fair approximation to accuracy is accepted it is found that the formula

$$\frac{C^3}{A} = R^3 \times 312 \times 10^{-7}$$

gives a fairly satisfactory expression in cases C, D, E and F, and in case B up to a value 9 inches for the radius of C. G., but is badly out for case A.

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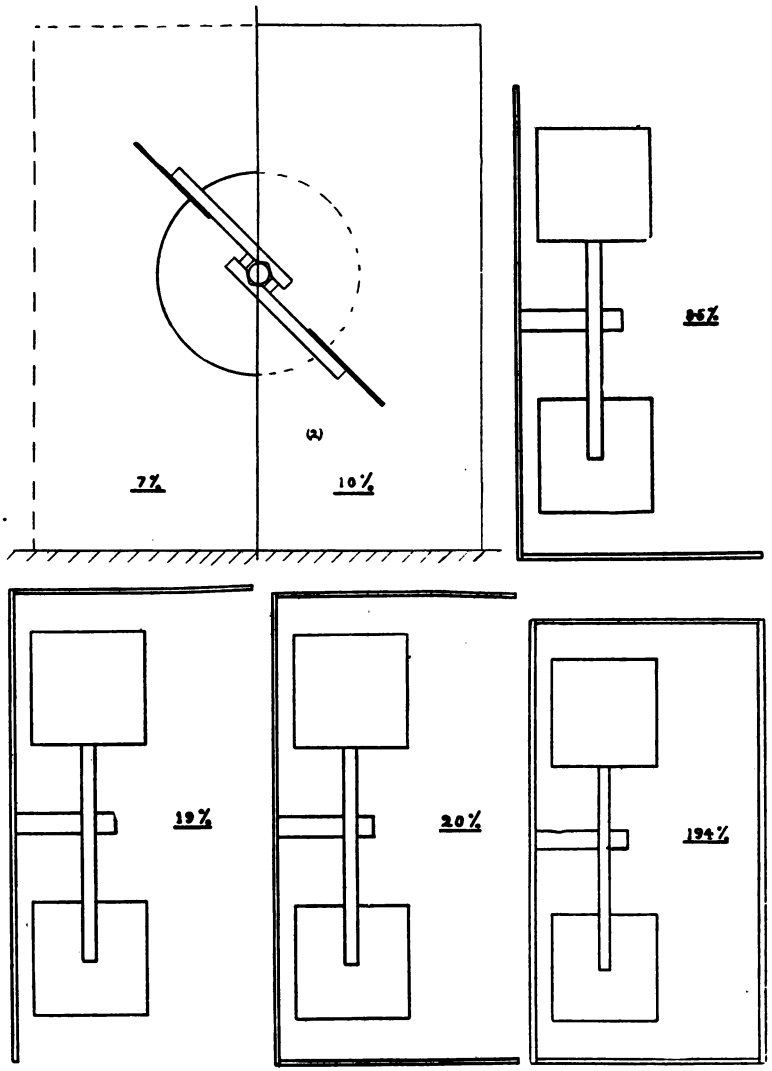


Fig. 15.

Figs. 10 and 11 show log $\frac{C^1}{A}$ plotted respectively against log Radius of the Center of Gravity of the plate, and against log Radius of Gyration. These values for $R$ are obviously impossible. Figs. 12 and 13 show log $\frac{given\ constant}{A}$ plotted against log Radius of the Center of Gravity

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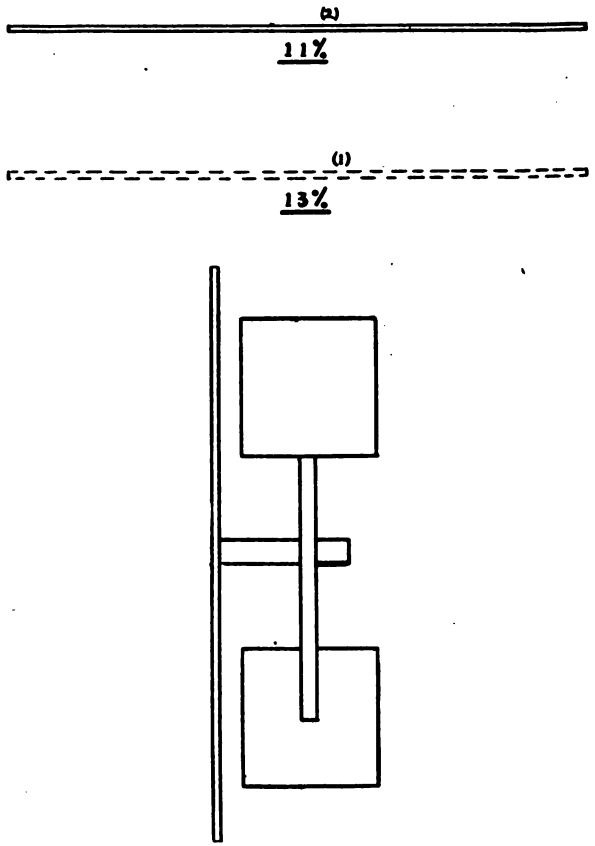


Fig. 16.

and against Log Radius of the Third Moment. In all cases the experimental constant is taken as the $HP$ absorbed at 1,000 revolutions per minute and $\frac{C^3}{A} = \frac{constant \times 1{,}000}{area\ of\ both\ blades}$. The curves G, in Fig. 9, are worked out from a formula given by Mr. Poppe for square plates.

$$HP = \frac{AR^2N^3}{4{,}010}$$

$A$ = area in square centimeters
$R$ = radius of outer edge in decimeters.

$$N = \frac{R.P.M.}{1{,}000}$$

$r$ = radius of center of gravity (given as 5.5 decimeters).

It will be observed that they fall below the results of F blades, but

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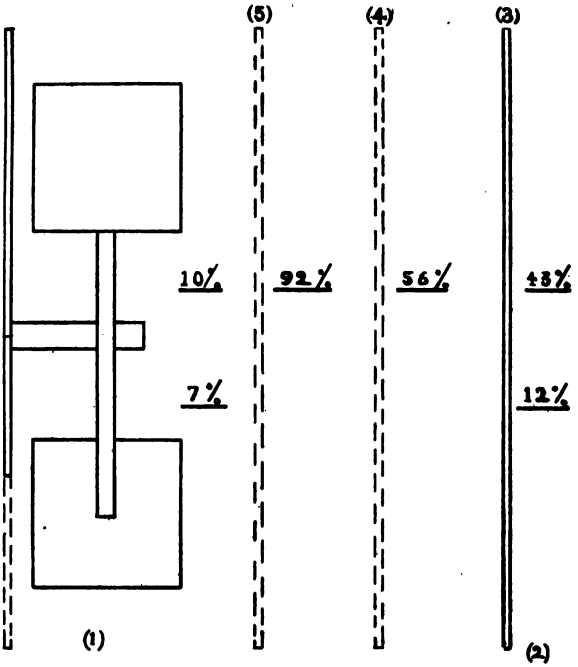


Fig 17.

under the environment conditions in which they are employed doubtless give fairly correct results.

The sizes worked out were 6 inches x 6 inches, 8½ inches x 8½ inches and 12 inches x 12 inches, the latter line being nearest F. The great danger in using this formula lies in the temptation to apply it for dimensions differing widely from those given.

## ENVIRONMENT

Some of the first experiments on the type of bed shown in Fig. 7 were made to test the effect, on the accuracy of the fan, of shrouding one side of the fan by means of various rings and disks, as shown in Fig. 14. Table III gives the results obtained, the left-hand column giving the numbers of the rings on and the right-hand column the percentage by which the horsepower from the formula $CN^3$ exceeds the measured horsepower. It is interesting to note that with the fan close to the flywheel there is an error of 5 per cent. and with one ring (No. 4) on, at about the radius of the center of the blade, the error is 20 per cent. It was next thought that it might be possible to calibrate a fan in a box of stated dimensions in order to cut out the environment factor.

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TABLE III

| Rings on | Percentage too high |
|---|---|
| Nos. 1, 2, 3, 4, 5, 6, | 11 |
| 1, 2, 3, 4, | 10 |
| 1, 2, 3, | 15 |
| 1, 2, | 7.5 |
| 1, | 5 |
| 0, | 5 |
| 5, 6, | 14 |
| 4, 5, 6, | 21 |
| 3, 4, 5, 6, | 14 |
| 2, 3, 4, 5, 6, | 11 |
| 4, | 19 |
| 0, | |
| (Fan clear 12 inches from frame) | 0 |

Fig. 15 shows the effects observed in building up the box, the floor forming the bottom.

(1) First a board, 42 inches by 36 inches, forming the back was inserted. The apparent horsepower was then 10 per cent. too high.

(2) One side, 42 inches x 18 inches, was arranged on the side towards which the top of the flywheel was moving; this appeared to reduce the effect of the back only and gave a figure of 8.5 per cent. too high.

(3) The side, as in (2), was removed and placed opposite—19 per cent too high.

(4) Both sides on—20 per cent. too high; very similar to (3).

(5) Back front and two sides—top open—194 per cent. too high; that is to say, the apparent horsepower is nearly three times greater than the real horsepower.

Fig. 16.—*Side Wall Effects.*

(1) Board at back, as in Fig. (1), and 42-inch x 36-inch board at side, as shown, 11½ inches from outer edge of blade.....13 per cent. too high.

(2) Similar to (1), but 21 inches away.....11 " " " "

Fig. 17.—*End Effects.*

(1) Disk of same diameter as flywheel, at back, apparent horsepower ..... 7 per cent. too high.

(2) As in (1), but 42-inch x 36-inch board parallel to disk 28½ inches away.....12 " " " "

(3) Board at back, as in Fig. 15, (1) and similar board in front 28½ inches apart.....43 " " " "

(4) As in (3), but 21 inches apart.....56 " " " "

(5) As in (3 and 4), but 14 inches apart.....92 " " " "

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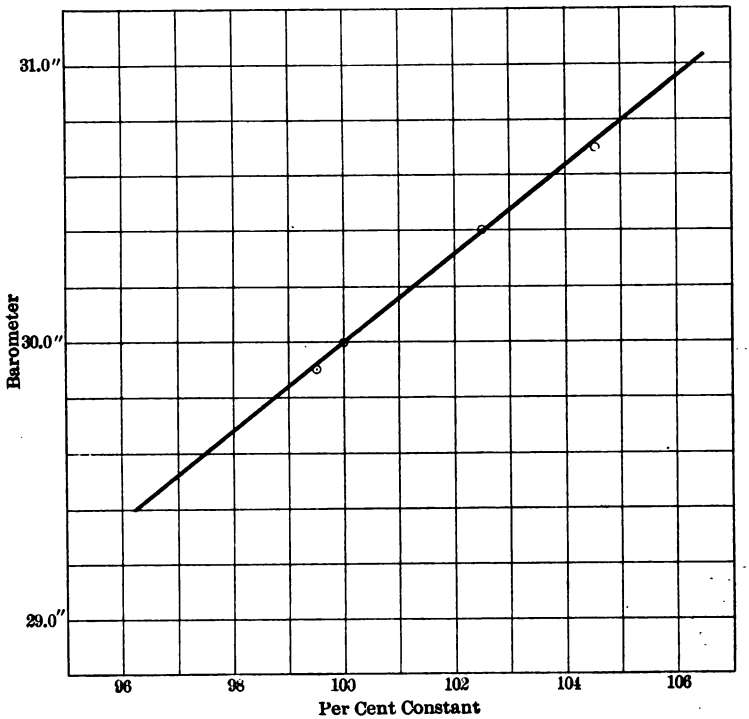


Fig. 18.

*Edge Effect*

In order to test whether the ratio of area to perimeter or edge exposed exercised any effect a pair of 8½-inch x 8½-inch plates was made perforated with a large number of holes (½ inch diameter), but the ratio $\frac{C}{A}$ was found to be unaltered.

*Barometer Effect*

This is shown in Fig. 18 and over the range observed during these experiments is almost double that which might be expected.

*Temperature Effect*

It is difficult to measure the temperature of the air actually taken by the fans as a considerable portion is drawn past the hot engine. For instance, in one case the experimental constant determined directly after the engine was started up was 105; after 10 minutes' run it had decreased to 100, the room temperature meanwhile increasing from 14 degrees C to 17 degrees C.

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*Draught Effect*

An electric fan was arranged to blow air onto the rotating blades; this was tried at different angles, but in no case was any effect observable.

*High-Speed Tests*

With the smaller fans, *A* and *B*, a geared-up arrangement was used (shown in photograph, Fig. 19), speeds up to 3,700 revolutions per minute being obtained. This gear was also used in determining the resistance of the arms, a pair of dummy wooden arms being shown in position.

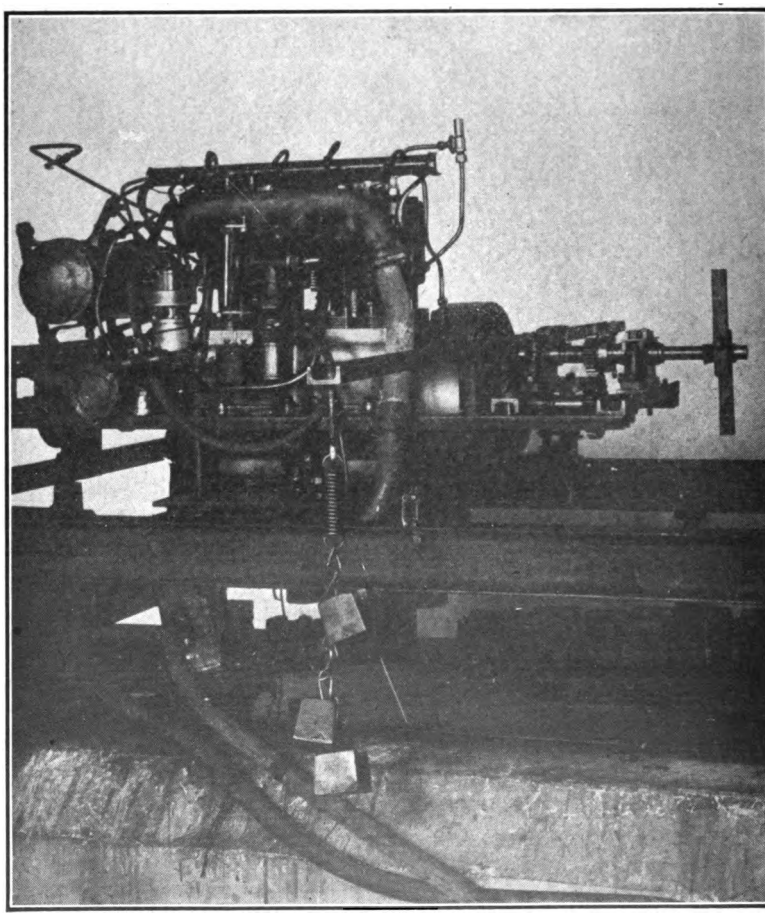

Fig. 19.

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C. P. GRIMES.—During the last two or three years I have followed the results of Professor Morgan and Mr. Wood, who have worked in conjunction, and consider them two of the foremost men in presenting to the automobile industry facts in relation to carburetion devices on automobiles. Therefore, I wish to make a motion that we extend to them a vote of thanks for the paper which Mr. Wood has presented at this time.

(The motion was seconded and carried unanimously by a rising vote.)

## DISCUSSION

JOHN WILKINSON.—Mr. Chairman and gentlemen, I have had a great deal of experience with fan dynamometers. I think I can bear out everything the gentleman has said in regard to the use of the same. We have found that for factory conditions it is a very satisfactory instrument to use. It is a very easy instrument to use. We have never considered that fan dynamometers approach the extreme accuracy which is necessary for laboratory tests of various engines under the various conditions in which they must be tried. We have always understood the great variations to be particularly noticed in regard to environment and have always been very careful that all our tests be made under perfectly similar conditions. The dynamometers should be calibrated accurately over all the ranges of speed which you expect to use. If you go above or below, you are very likely to get mistakes. Whenever we have had occasion to change the physical aspects of the testing room, we have found it necessary to make recalibrations. But where the conditions are kept uniform, the curves of horsepower will generally follow a definite law. As I remember, the power curves are always proportional, not to the cube of the speed, but to an exponent slightly under the cube of the speed, something like 2.97 or 2.98 varying slightly with different sizes of blade used.

I would always be suspicious of any horsepower curves made on fan dynamometers where the speed relations are extreme, unless the dynamometer had been calibrated over the whole range of speed. But where the limits are definitely settled, I think that with proper care the results can be made accurate enough to meet the conditions of any manufacturer.

HERBERT CHASE.—I have been very much interested in Mr. Wood's paper. The statements he makes are, I think, exactly in accordance with the facts as I have been able to observe them. The fan dynamometer, as Mr. Wood states, is a very cheap and very convenient form of dynamometer. But it must be used with exceptional care if accuracy in results is desired. I consider it one of the best forms for commercial use. It gives a steady load and does not require much attention from the operator. I speak particularly of "running-in" tests.

For exact scientific tests it seems to me most desirable that the fan-brake be used in connection with some means of measuring the torque reaction of the motor. That also Mr. Wood has indicated. If this is not done it is very easy to fall into some of the errors which Mr. Wood has pointed out, due to environment and to atmospheric conditions. I would like to call attention to the table of correction for barometer and temperature change which Mr. Renard has published in a paper on the subject.

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One of the great disadvantages of the fan dynamometer is that in almost all forms it is necessary to stop the dynamometer and alter the position of the blades in order to change the load. This fact alone makes it much less convenient than the electric cradle type, which I consider the most convenient of all. The saving in time alone over a period of two or three years seems to me sufficient to offset the great difference in first cost.

T. B. BROWNE.—Mr. President and gentlemen, it may interest you to know that the fan dynamometer is used a great deal in our factories in England for comparative tests. The more delicate work of testing a new model or setting the standard of an engine, that is deciding the horsepower which shall be required from all engines of that model, is usually done with either the electric cradle dynamometer or rope friction dynamometer used in conjunction with a spring balance. The fan dynamometer, as Mr. Wood has said, is so very sensitive and liable to many corrections that I think it is not suitable at all for obtaining very fine results. But for comparative purposes and bringing the engine up to the standard required, I think there is nothing to beat it. It is very cheap and simple to fit; it is of course quite easy to arrange for each engine to be put on test under precisely the same conditions and surroundings; and it is not a very difficult matter to make temperature and pressure corrections. The electric dynamometer is, of course, an expensive outfit. Some of our smaller makers have therefore confined themselves to the use of the rope dynamometer. In the hands of people who have had experience with it I think you can obtain very accurate results.

H. L. HORNING.—Mr. President, inasmuch as the weight of the air determines the power absorbed, is it not necessary that the change in humidity of the air be noted in the readings?

E. B. WOOD.—We take readings with wet and dry bulb thermometers and really have not noticed any difference. But I would like to point out that the barometer and the thermometer together can within reasonable limits effect a variation of twenty per cent. I do not know whether you will allow that amount of variation in your commercial testing. I thought that ten per cent. would pass for testing.

F. JEHLE.—I was very much interested in Mr. Wood's paper and agree with him in nearly everything he has said. Being particularly interested in the eddy current magnetic absorption type of dynamometer, I do not quite agree with him as to that. I think this form of dynamometer, if any, may be made to handle high torque at low speeds. In fact, I have seen one in use that did this. Of course, where it has all the necessary refinements to do this, it is no longer a cheap dynamometer. Still it possesses the advantage of being self-contained; that is, has no resistance girds or switchboards. As far as the warping of the disc is concerned, I have known of no trouble that way. Of course, I used a water-cooled one.

The remark about the water brake that it is compact for power was rather interesting. This is true, however, at comparatively high speeds only. I have never seen a water brake that could be used at very low speeds unless it was extremely large.

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W. C. LAMKEN.—From data given in the German handbook for engineers, the Hütte, I have developed the following formula, which seems to be sufficiently correct for commercial use:

$$\text{brake-horsepower } HP = C\ m\ N\ n^3\ (\ (B-b)\ (R^4-r^4) + b\ L^4)$$

where

C = a constant.
m = the specific gravity of the air
N = number of blades
n = number of revolutions per min.
B = width of blade in inch. measured parallel to the shaft
b = width of beam in inch. measured parallel to the shaft
R = radial distance of outer edge of blade from center of shaft, inch.
r = radial distance of inner edge of blade from center of shaft, inch.
L = radial distance of outer edge of beam from center of shaft, inch.

In three complete sets of curves on hand I found the following values of C m:

$$C\ m = 6.4 \quad 10^{-15}$$
$$C\ m = 6.4 \quad 10^{-15}$$
$$C\ m = 7.8 \quad 10^{-15}$$

With these values used in the above formula the figures obtained differed less than 5 per cent. from those taken from the corresponding points of the original curves.

E. T. BIRDSALL.—I would like to ask whether anybody has used circular instead of square blades. In all the data I have on fan dynamometers square blades are specified, and it has always seemed to me that there would be some effect due to the corners, which may account for the difference between small blades and large blades, the difference in the corner area relative to the total area of the blades.

E. B. WOOD.—We made some experiments rather with the idea of testing what I have called edge effect, that is, the effect of altering the ratio of area to perimeter. In a pair of the 8½″ by 8½″ blades we drilled a lot of ½″ holes, reducing the area to about three-quarters of what it was previously, and increasing the length of the edges tremendously. On testing, it was found that $C/A$ was as nearly as possible the same as that of the solid blade. Some of the $F$ results are on rectangular blades of the shape illustrated in Fig. 2, and not necessarily on square. I have not tried any circular ones.

BERNARD NAGELVOORT.—In the paragraph on water brakes Mr. Wood says that a water brake is very expensive and requires a flexible coupling. I developed a water brake a few years ago which can be manufactured very cheaply. A single handwheel, the size of an ordinary valve-wheel, puts it completely within the operator's control. We have also developed a type without the controlling feature, thus putting it in a class with the fan dynamometer. Inasmuch as it puts only a given load on the engine at a given speed, by having it previously calibrated the operator can tell exactly what load the engine is carrying by merely taking tachometer readings.

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# GENERAL INSPECTION METHODS

By E. F. Roberts

There *is* no more positive evidence of the general desire among American manufacturers today to deliver to the buying public a dependable product, honestly made, than the general interest in inspection methods. There *should* be no more satisfying proof to the buyer of a motor car that the vehicle represents the utmost possible limit of safety for himself or his family than the knowledge that its construction has been safeguarded at every step, from raw material to finished assembly. The progressive manufacturer realizes that the only assurance of permanent prosperity lies in the excellence of his product; and eternal vigilance is the price of excellence. Inspection, close, constant and rigid, is thus imperative to maintain the quality in the product and, although when adequately enforced, one of the most costly features of a motor car organization, it must be recognized as one of the most vital. Realizing structural strains at the average speed of a powerful car and the gravity of possible flaws or breakage, it is obvious that to the purchaser the most essential consideration is the certainty that every detail of material and construction has been subjected to the most severe and searching test that skill can devise for his protection. Absolute interchangeability of parts is also an essential for rapid and economical production and modern inspection with quick-acting gage systems constitute the indispensable factor of attaining this result.

In large industries, perhaps the first feature that should be considered in an inspection system is the relation of its personnel to the rest of the organization. To secure the determined and inflexible adherence to the standards of quality and workmanship laid down by the management, members of the inspection department cannot be in any degree subject to the control of any shop foreman or any executive directly producing. Evidence to this effect is so common to the experience of all factory executives that the principle scarcely needs mention, but its expression is justified by the fact that in spite of this, scores of organizations either through ignorance of their own situation or indifference permit such conditions to remain. It is an emphatic axiom that the average workman thinks of his job first and duty afterward; and an inspector refusing to pass defective work for a foreman who can discharge him is, commercially, an imaginary quantity.

For convenience of administration the Packard plant is organized into six productive divisions designated as Chassis, Body, Truck, Forge, Foundry and Service Divisions. Each division constitutes a unit in itself not only as regards productive organization, but also as concerns its inspection force. Each division's inspection corps is in charge of a general head and over all the divisions extends the authority of the chief inspector. This executive is responsible directly to the general superintendent, is personally a thorough and experienced mechanic, familiar with general engineering practice, standards and limits, and also an expert as regards



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manufacturing conditions, gage systems, tool design, etc. With his assistant and through the division heads and foremen inspectors he is in direct control of every inspector in the plant. Foremen inspectors may to a limited extent perform actual inspection work, but their duty is essentially that of maintaining the efficiency of the men and methods under their supervision. They must be actively watchful of the care used in checking parts, must see that all parts brought up are handled promptly and that gages and instruments are properly used, and, above all, kept continuously in first-class condition. Through their personality the policy and standards of the entire inspection system must be impressed upon every individual in it and the quality of their department output is a standard for which they are directly responsible. Regular department foremen may report infractions of discipline by inspectors and have prompt action taken by the chief inspector, but individual inspectors in departments are wholly free from any constraint in criticising poor workmanship. Every operation and every part is passed or rejected absolutely upon its conformity, or lack of it, with the blue print. There are large placards conspicuously posted in every department warning inspectors that immediate discharge will result from passing work on any other basis, except written authority of a general executive. Every possible means is thus employed to impress upon the inspectors that their sole responsibility is the maintenance of quality, and that their positions depend upon this and nothing else. An inspecting force, although necessarily recruited from various sources, should consist mainly of men of previous experience and training in other mechanical departments of the plant. All inspectors should further, when first assigned to this duty, be placed in company with an experienced man and their work carefully watched for a number of days before giving them individual assignments. Special care should be exercised in selecting and examining them, they should be well paid and every possible effort made to hold satisfactory men permanently on the line of work in which they have become expert. A graphic organization chart is herewith given to indicate the relations of the various branches of the Inspection Department.

## LIMITS

The function of an efficient inspection department should begin even before the drawings are approved in the engineering department. The chief inspector should be *ex officio* chairman of the limit committee, whose duty it should be to pass on all drawings to determine whether the limits assigned by the designer are commercially practicable, thus ensuring the elimination of many possible sources of later friction and delay. After the drawings for a new design are approved and signed by the limit committee, and not until then, they should be issued to the various functional divisions, the set in which the inspection department are interested being those sent to the tool room. These, of course, should be checked over to determine the new tools and fixtures required—and also on the inspection department's behalf—to determine the new gages necessary, preparation thus being under way for the inspection of the finished product, in some instances, even before the raw material is ordered.

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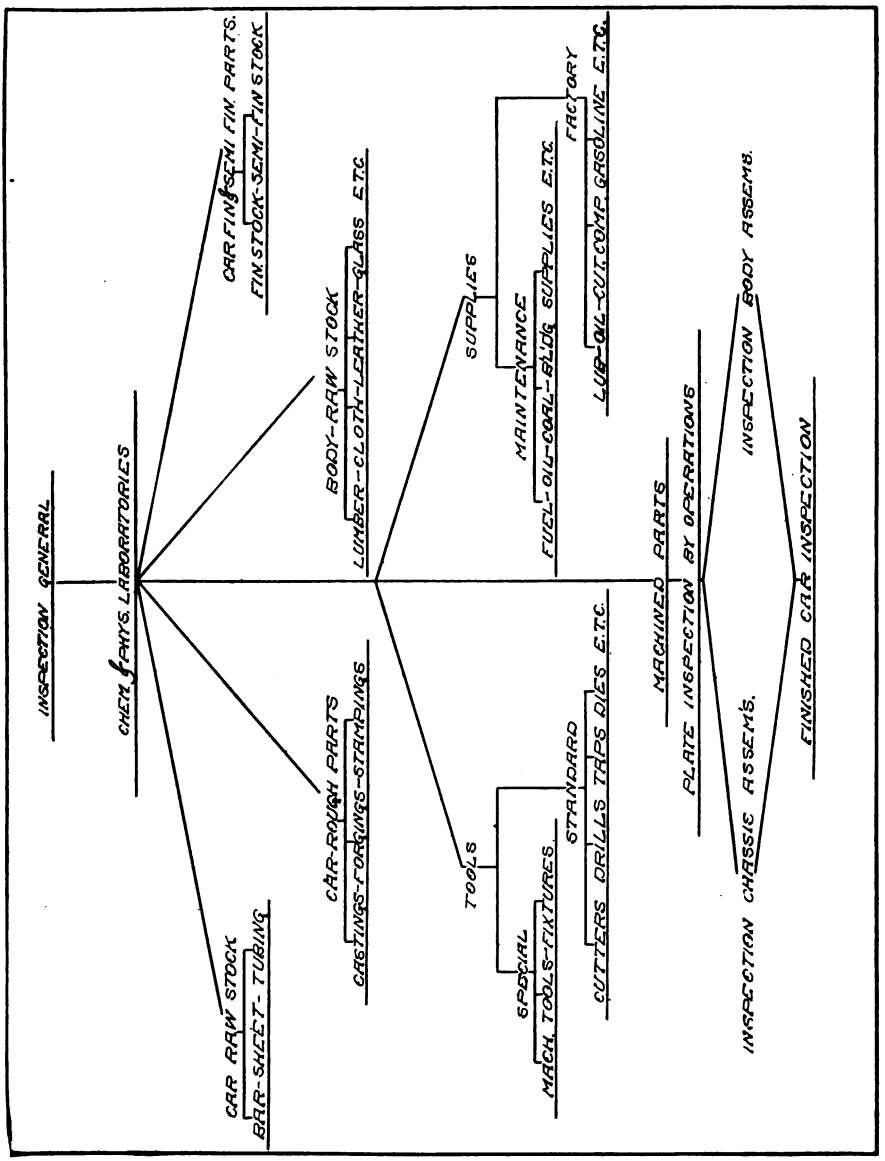


MATERIAL

Material, as will be noted from the chart, should for inspection purposes be divided into raw stores, including bar, tubing and sheet metal; car parts rough, comprising castings, stampings and forgings; body parts

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rough, such as lumber, leather, glass, trimming fabrics; and car parts finished and semi-finished. To insure uniformity of composition and quality all metals should be bought on the basis of standard analytical specifications, developed by the engineering department through laboratory test and research. Supply firms, before making up an order, should send in sample test pieces for approval, ensuring in this way almost invariable conformity with the specifications and eliminating delays and arguments. In the case of ordinary bar stock, as soon as a consignment is received and checked in as per invoice, it should be inspected for size, limit snap gages being used and each end of each bar being checked. Straightness also should be noted, as occasionally a bar may be found that would not pass readily through the machine collets. A bar should then be selected at random and a test piece 3 or 4 inches long sawed off. This should be tagged with the date, amount of consignment, grade of metal and the purpose used for, and forwarded to the laboratory for analysis.

The laboratory is exceptionally complete and well equipped for analytical and physical research. It is in charge of a chemist and engineering specialist of wide experience. Special rush service can always be had from a laboratory of this description in twelve hours, although ordinarily two days are allowed. As soon as the test piece has been removed, each bar should then have the grade number and date stamped on the end and the consignment should be placed in the regular rack pending receipt of the laboratory release. After analysis the duplicate stub from the specification tag will be removed by the laboratory and returned to the stock department, thereby either releasing the consignment for factory use or rejecting it as unfit. If the analysis is satisfactory, the stock-keeper should then paint the ends of all bars in this lot with the standard color for that grade, indicating its readiness for use. To ensure this method being given proper attention, personal instructions must be issued, and as a further precaution, signs should be posted warning the men that painted ends must never be cut off and that all bars must be placed in the racks, painted ends out. If the laboratory analysis shows the sample below grade limits, the stock department should notify the purchasing department and arrangements should at once be made either for the return of the consignment or its substitution for any other use for which it may still be fit. Bar stock intended for special use, such as piston pins, universal joint pins, etc., or selected stock, should be kept in special separate bins.

The same general method should be followed in the inspection of tubing except that it must be checked for inside diameter or thickness of wall, as well as outside diameter, and also for eccentricity. Standard sheet metal, aluminum, brass, copper, steel galvanized sheets, etc., from established firms need ordinarily be checked only for gage and general appearance and accepted without analytical test. In the case of stamping stock, however, a test strip 1½ by 12 inches should always be submitted for analysis and tensile test. In such instances the same procedure would be gone through with as in the case of bar stock, except that a different method of marking (surface stamping) must be used.

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For ensuring the correctness of forgings the regular practice should be to submit a lead proof for a preliminary check before the dies are hardened. The lead as soon as received should be delivered to the purchasing department for record and forwarded by them to the engineering department for general checking as to design specifications. If satisfactory it should then be transmitted to the tool department, where it must be laid out and carefully gone over in detail with the drawing, and this opportunity should also be improved for comparing it with the design of any fixtures and gages relating to this part. As soon as this check is completed the tool room inspector should immediately advise the purchasing department as to approval or rejection. If approved, as soon as delivery of forgings begins, a few of the first may be selected at random and again checked over in every detail to cover any possible deviation on the dies or negligence on the part of the operator. Important parts subjected to heavy stresses, such as axles, steering levers, steering knuckles, steering worm, transmission gears and parts, should invariably pass the analytical test for every consignment before being released. Once the correctness of the dies has been established, forgings need not individually be checked for detail specifications, but every one must still be carefully examined for flaws, cold-shuts, etc., and every now and then a single forging should be again inspected in every detail of dimension and material to ensure the continuous maintenance of the original standard.

Patterns for castings should in every instance be closely checked by a special inspector before being released for use, thus eliminating chance of error as much as possible, in the initial state. As soon as the first casting from any pattern is completed it should be at once forwarded as a test sample and submitted to the same inspection and detail checking as that given forgings and the same routine may be followed in rejecting or accepting it and approving delivery. In the foundry test bars are run from every melt and regularly analyzed and tested for physical properties. Individual castings are inspected in detail as received, although not laid out for every operation. In general casting inspection cored holes and bosses should, however, be checked to discover any possible variations due to core shift and the entire casting should also be carefully examined for sand- or blow-holes. Doubtful places must be tapped with a hammer, or to determine leakage, tested with gasoline. The scleroscope test may also be employed in case trouble is experienced on account of excessive hardness.

Body stock also should be inspected, the lumber being scaled and examined for quality and soundness, while leather, cloth, glass, etc., should each be checked over by experts in these lines. Paints, oils and varnishes should be bought both on analytical and weathering tests. A year's exposure to sun, wind, rain and sleet is none too strenuous a test for body varnish. The passing of all finished parts, from miscellaneous supplies and tools to occasional car parts bought finished, should also be within the jurisdiction of the inspection department and conducted with the same unvarying fidelity to standard quality and specifications as observed in regard to all other items. The essential features of an efficient material in-

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spection are, first, that nothing must be left to the individual judgment or opinion of the inspector. Every specification should be based on the most thorough engineering or mechanical research and embodied in drawings or written instructions. The second and equally important consideration is that the inspectors must absolutely be under no constraint as regards the question of production. However badly the factory may need material or parts, the receiving inspector must not recede in the slightest degree from his standards. He must be held responsible for the maintenance of quality alone. Production to him should be a matter of absolute indifference.

The foregoing methods and regulations for the inspection, analysis or test of all stock and parts entering a plant are intended to and, we believe, do guarantee the quality and fitness of every item of material comprised in the car. Perfect material is, above all else, the requisite of first importance. *Poor workmanship* may spoil *good material,* but no amount of *good workmanship* can ever redeem *poor material.*

### FACTORY INSPECTOR

Factory inspection of parts in process in a large organization can be best conducted almost entirely on a departmental basis. In a small plant a central inspection department possesses certain advantages, but with the growth of any business, the time required for trucking and handling must eventually make this method obsolete. In each department a central location should be selected, well-lighted and convenient, and here at inspection plates should be installed the head inspector and his assistants. The inspection plates used in the Packard factory are of cast iron, 24 by 57 inches, and of massive and rigid construction. They are planed and finished on top to an accurate surface and carefully used and looked after, being covered every night with a coating of oil and frequently tested for trueness. At these sit the inspectors, provided with blue prints covering every part handled in the room and with standard or special gages for checking every operation; and to them are brought all the various lots of parts as fast as completed in each operation.

### GAGES

The greatest factor in quick and thorough inspection is an efficient system of gages. There is no more common fallacy in manufacturing than the assumption that a correct set of gages once issued insures accuracy of workmanship. And another general fallacy is the assumption of correctness for the gages themselves. Ordinarily the micrometer is accepted as the standard of measurement. When, however, it is remembered that the average micrometer will alter merely by the heat of the hand to an extent of two ten-thousandths, it is obvious that the court of final appeal for accuracy must be a higher one. There can be a no more absolute precision standard than the Johannson system of gages. A set of these gages consists of eighty-one blocks, increasing in size by graduations of one ten-thousandth of an inch. They are manufactured in Sweden, the completion of a single set requiring about five years and the surfaces when finished being so perfect that atmospheric pressure will hold a dozen of them

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suspended in a cluster from one held between the fingers in the same manner as though magnetized. In addition to their almost infinite accuracy they are so impervious to variations of temperature that one of them may be carefully checked in a warm room with the most sensitive instrument possible and then after being laid on ice again checked without showing the slightest variation. These gages may be accepted as the final source of authority on the accuracy of all manufacturing dimensions. They should serve as the check for all master gages, which in turn check the shop sets. Special gages, of course, must be designed in the tool draughting room as soon as the original design of a new model is issued. Standard gages, however, are required in such large quantities and the efficiency of any inspection system is so dependent upon their immediate accessibility that standard blanks for snap, plug and ring gages should be carried in stock at all times. These may be made up rapidly and at low cost principally on automatics, leaving only sizing and finishing operations for the toolmaker. This method renders gage equipment so readily accessible that there is no incentive or excuse for negligence in this respect. All rough stock sent into the factory in dimension lengths should be cut to gage in the stockroom. The workman who machines it should have a gage for his operation which is a duplicate of the inspector's. The inspector's gage is thus a check on the accuracy of the workman's gage, and all the inspector's gages should be in turn checked at regular intervals with the master gages held in the tool room. Too much emphasis cannot be placed upon the importance of properly checking and caring for the master gages. The set should be at least sufficiently complete to cover every important part. They should be given not less than three different checks with the Swedish master blocks by three different inspectors and these separate readings reconciled before being approved for use in the first place. They should be kept in vaults under lock and withdrawn only on fixed occasions or by some executive's order and then only by the man or men regularly assigned to the duty of handling them. No attempt should be made to use them indiscriminately for checking shop gases, as their function should be the control of the inspectors' gages only. Every gage in every department should be turned into the tool-crib at the close of working hours. Some of the more important ones must be checked daily before issue and very few should be permitted to be used unchecked for more than a week. Limit thread gages in particular must be checked with the master gages every few days for accuracy of dimensions and depth of thread.

All gages must be sized to the limits shown on the print and only parts coming inside these limits passed. Parts outside the limit, except where the defect is a nominal one only, such as oversize, may be sent at once to a central checking station. All parts received here should be examined daily by the chief inspector or his assistant and the division superintendent or his assistant. The reason for the defect should be clearly determined and if tools are at fault the proper correction at once made. If, as is usually the case, the cause is negligence on the part of the operator, the foreman's attention must be called to it and both he and the operator warned against a repetition. In the department itself, the inspectors, as

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soon as a defective lot of parts appears, should issue to the foreman a written "stop-notice" or warning that a certain operator or certain machine is producing work below standard. This will insure immediate attention, as it puts the responsibility squarely up to the foreman. When all the operations on a given part are completed in one department, the inspector's O. K. should be again required before they can be forwarded to the next one. There is no possibility under the Packard method of any lot of parts accidentally escaping inspection. The operator's pay, for every lot and every piece worked on, is absolutely contingent on the inspector's O. K. and every workman for this reason is continuously watchful to prevent negligence on the part of his department inspector. Even dishonest inspection has little incentive since the time-slips on file bear so complete a record that the responsibility for such work may be very easily determined. Thus at every step in the progress of a part it is possible to so check and safeguard it as to ensure its conformity to the standard of quality. To illustrate in detail a thorough method of supervising the maintenance of inspection standards, we may follow the development of a typical forging, the bevel driving gear, as carried through its various operations in the Packard factory. In one respect this gear is given special inspection by receiving a supplementary analytical material test. The steel from which it is forged is given the regular laboratory analysis before being released to the Forge Division, but, in addition to this, because of the importance of the part in regard to both strength and quiet running, a material test is taken on each lot of forgings received. The blanks after release are heat treated and then sent to the lathe for boring and reaming the larger opening for the differential casing and for turning the face of the web. The blank is then sent to the plate and the dimensions and surfaces checked. The piece is next taken to the milling machine and the four slots for the differential spider are cut. For the second time it goes to the inspector, to determine whether the slots are central, at right angles to each other, square with the surface of the web and true to size within the limits. Next the outside diameter is rough-turned and the face angle finish-turned, making necessary the third trip to the inspection plate. Again the blank is sent to the lathe for finish-turning the outside diameter and the back angle and sizing the width of the tooth plane. This makes necessary the fourth inspection, after which it is sent to have the face of the tooth-plane ground to the correct angle with the web. For the fifth time an inspector checks it before it is passed on to have the back of the web surfaced preparatory to copper plating for hardening. After plating the teeth are rough and finished cut, which makes necessary inspection No. 6. The gear is next sent to the heat treating department and first pack-hardened or carbonized. In the carbonizing pot along with each lot of gears is placed a test piece of the same material as the gears, about 6 inches long and ½ inch square. After the specified interval for this grade of steel, the gears and test bar are removed, cooled and reheated for hardening. After hardening they are cleaned and the test bar is broken and checked for depth of case, fineness of grain and general structural appearance, as an index of the internal condition of the gears.

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The gear is now ready for the most important of all its inspections, the strength and hardness test. Hardness is measured by the scleroscope, which compares the condition of the part with that of a standard established by the Brinell testing machine. Between thirty and forty readings are taken from each gear. Strength is determined by the hammer test, a device which permits the concentration of a heavy blow of known force on a single tooth, each gear being given this test on at least four different points in its periphery. These tests may be considered as inspections Nos. 6 and 7, and are immediately followed by inspection No. 8, which is the test applied by a special fixture for determining the amount of possible distortion due to heat.

When successfully past this inspection the gear is ready to be ground on its outside diameter and on the face of the teeth and this in turn leads to inspection No. 9. Another grinding operation on the back and face of the web and again an inspector must check the accuracy of operator and machine, this time permitting a limit of variation of only one-half-thousandth. The final grinding is the finish of the opening for the differential case, which is followed by inspection No. 11. The last machining operation is the drilling and reaming of the differential casing bolt holes, which, in inspection No. 12, are checked for size and spacing. Absolute conformity to specifications is the standard for this operation, no variation being permitted. Not yet, however, may the gear be released as a finished part, as it may still fail on No. 13, the final inspection. This consists of a test on a special fixture again, for checking the correctness of the tooth-bearing and smoothness of roll, and but little less than perfection is required of the gear that is finally passed through. As a finished product it is obvious that a large percentage of the cost of the gear is due to the continual supervision of the inspector, but it should also be equally obvious that the result is an article as near to the ideal of mechanical perfection as the best of equipment, skill and scientific testing can produce.

The routine of gear inspection, while in some respects more complicated than that necessary to follow in the case of minor parts, may nevertheless be noted as typical of the spirit and purpose of a thoroughly efficient inspection. Where such standards are persistently enforced day in and day out, half the object of inspection—that is, the *prevention* of poor work—is in large part accomplished. The certain knowledge that incompetence or negligence will be infallibly detected and immediately dealt with is the most efficient means of eliminating such faults.

In addition to the parts inspection, which should cover every item purchased or made for the car, all assemblies from the gasoline tank draincock to the complete motor should be checked in detail, both for accuracy of relation of their parts and for operation. The minor assemblies must be checked by themselves and then later as parts of large assemblies for location and function. This progression should follow through all the various stages of assembly, culminating in the motor, for instance, in the motor test room, where the engine, speeding under its own power, may be checked for every phase of construction and efficiency by its showing in operation under full service load. As a part

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of the chassis assembly it is again due to be checked, along with the others, for perfection of adjustment in the chassis road test. Bodies should be inspected—in the beginning, part by part—wood, glass, leather and cloth. Before entering the paint departments every one must again be gone over inch by inch and every minor defect, whether dent in aluminum or check in wood, sought out and corrected. Another inspector will pass it from the paint shop into the trimming department, and an expert trimmer's inspection O. K. should be required to get it from this department back into the finish varnish room. Before it is sent down to be attached to the chassis it must be given a last careful examination for any possible defects of finish or workmanship, and in the finished car assembly department meet a chassis, which has come through only after a similar ordeal in its own paint department. After the car is assembled it should be inspected and checked with the specifications on the sales order for completeness and workmanship before being passed to the finished test department. Preparatory to the road test the motor is to be tuned up to the finest possible pitch of adjustment and inspected for quietness and flexibility. As this test covers road performance it should be entrusted only to men of long experience and special aptitude and judgment. There remains only the attaching of any special equipment or accessories and the formal checking out of the car before submitting it to still another inspection, the most severe and critical of any it has had. The sales department has charge of this feature and their attitude should represent as nearly as possible that of the buyer. Not being subject to the control of the discipline of the manufacturing department in any degree, they are free to exercise their judgment without fear or favor on every detail of construction, operation and finish. Their decisions are positive and final, and the car that, in their eyes, falls short of the desired perfection is rejected until brought up to this ideal.

## DISCUSSION

PRESIDENT MARMON.—The inspection department of any factory was commonly considered the most important department it has, until Mr. Leland told us the other night that we ought to throw it out. (Laughter.) Has any one any comments to make on this paper?

E. W. WEAVER.—Mr. President, I have been very much interested in this paper, as it is on a subject to which I have given considerable study. I would like more definite information as to the accuracy with which bar stock, tubing and so forth is inspected. The writer refers in one place to selected stock. Is this selected by the inspection department or is selected stock bought from the maker?

RUSSELL HUFF.—We buy selected stock. We specify it to the mills, they roll it and have it come to us within certain limits. That saves a great amount of machining. You can buy bar stock and tubing within a very few thousandths of the finished sizes. With a small amount of grinding it can go right into finished stock.

E. W. WEAVER.—I would like to call attention to the limits which are given on an S. A. E data sheet in regard to steel tubing.

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They are given as plus or minus five-thousandths of an inch. That is not accurate stock by any means. It seems to me the limits should be graduated to the diameter rather than be arbitrary for all sizes.

HENRY SOUTHER.—The inspection of material is very important and I think even Mr. Leland will admit that it is a part of the inspection that we must not drop out. My experience indicates that the greatest damage done by the purchasing department is in not ordering far enough ahead to make possible inspecting the material before it gets into the shop. Too often steel lands at the siding and goes into a tool for machining before anybody knows what it is. That is a great misfortune, because once in the shop, one bar of steel or one lot of steel, in gears or something else equally important, will do no end of harm. I believe that if the designing and order departments would plan far enough ahead to be able to hold the steel up when it is received until its identity is fully established, the improvement will be very wonderful.

F. E. MOSKOVICS.—In the chart given in the paper the chemical and physical laboratories seem to play rather an important role in control of materials. What relation does the chemical and physical laboratory play in the inspection of the materials? In the heavier steels how do you control the tests? Do you continue them through the entire run of steel, or use the chemical and physical laboratory merely for occasional research work?

RUSSELL HUFF.—The chemical and physical laboratory has been turned over practically to the manufacturing department of our plant and is used there for inspection. In the first place, we depend on the chemical and physical laboratory to establish our specification standard. We have written specifications for every grade of metal and other material which we use in the entire output. These specifications are spread around the plant, in the purchasing department, engineering department, stock department, in such a way that the material is ordered according to them. As pointed out in the paper, in the case of a very important quality of steel, we may get a small sample bar from the mill first to see if it is satisfactory to us, comes within out ideas of the limits of our specification. If it is satisfactory, the entire shipment is sent in. From the carload lot small samples are cut from a certain number of bars, one in ten or one in a hundred or one in a whole lot, depending on what the material is. We have a regular form for handling this in a routine manner, worked out by the engineering department and handled in a systematic way by the manufacturing department, so that the purchasing department, the stock department, the drop-forging plant and all interested in the material know exactly what is in the carload, how the material runs as to carbon, nickel, chromium content, or whatever it may be.

If the material is not up to specification, we have the privilege, of course, of accepting and using it in some place in the car other than originally intended, where it can be used without any trouble or danger.

G. F. FULLER.—I would like to call attention once more to the importance of testing the physical properties of the metals in both bars

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and forgings. The specifications you put out can have no effect unless you take some such action to determine that you get what you specify. This came to mind particularly forcefully a while ago when there was brought to our factory a pair of steering knuckles. The owner of the car in question had already broken two. He wanted us to make some forgings so that he could be sure of what he was putting in. He was tired of wrecking his steering apparatus. I cut some chips from the steering spindles to analyze the metal. It was all right, about .38 carbon, low in phosphorus and sulphur, manganese about .55. There was no reason why the steering knuckle should not have given good service. The design was a bit light but all right for average use. We cut a test specimen from one of the spindles that had broken, and pulled it. It showed 35,000 elastic limit and 35 per cent. reduction of area—positively ridiculous. I do not doubt that the people who put that steering spindle into their car covered themselves so far as the specifications went, but they did not look at all to see what they got.

It is stated in Mr. Roberts' paper that "every now and then a single forging should be inspected in every detail of dimension and material, to insure the continuous maintenance of the original standard." You must test more frequently than "now and then"; you have to test all the time. It being entirely possible to have inspection made by the forger, if you do not want to take his word for it, get coupons forged on the piece so that you can make inspections from them (one in ten is fair) without spoiling the piece.

RUSSELL HUFF.—There are, of course, a great many forgings used in a car, some three hundred. Mr. Roberts in his paper means that it is only necessary to test a forging now and then, but there are special exceptions to the rule. In the case of the large driving bevel gear we use in the rear axle, we go so far as to analyze practically every blank that comes in, to see that the steel is just right. After it is finished every tooth is tested for not only hardness but strength on a drop-hammer special machine. There are two extremes, you might say, in testing and inspection work. Simple forgings which are not of special importance to life and limb do not have to be tested like other forgings which are.

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# MALLEABLE IRON CASTINGS

By Enrique Touceda.
(Member of the Society.)

Although malleable iron, as compared with steel, enters into automobile construction to a limited extent only, the actual amount used in the industry is large. I believe it will be admitted as a general proposition that the constructing engineer, while very thoroughly posted on carbon and alloy steels, knows less about this material than possibly any other passing through his hands.

There is a widely prevalent misconception that when any part of a malleable casting exceeds three-eighths of an inch in thickness of section, the change that normally takes place during the annealing process, whereby the hard and brittle white iron castings that come from the air furnace are converted into soft, tough and ductile ones, is in this case but imperfectly accomplished.

The malleable iron process is conducted in two steps, the first of which consists in melting gray pig iron upon the hearth of an air furnace, when a certain amount of the original silicon, carbon and manganese is oxidized, and thus removed from the iron while it is being melted and subsequently raised high enough in temperature to successfully run the castings. The following three facts are well known to those who possess even an elementary knowledge of the metallurgy of iron and steel:

First, most of the carbon content of gray pig iron exists in the form of graphite; that is, free; if a pig be broken and the fractured end be gone over with a stiff brush, it is easy to thus remove the exposed little flakes of graphite held in mechanical mixture with the iron and always separated from the iron during and for an interval after solidification.

Second, when pig iron is uniformly white in fracture, no graphite is apparent upon inspection; instead of the carbon separating out in whole or in part as graphite, it is all combined with the iron *chemically*.

Third, a pig iron having most of its carbon in the form of graphite, can be changed into an iron in which none of its carbon will separate out as graphite if this pig iron be melted in such a manner that a certain amount of its silicon content be removed from it through oxidation; for if the silicon content be in excess of a certain amount, it prevents the carbon from combining chemically with the iron; if it be removed gradually from a pig iron in which the carbon would normally have existed as graphite, a point will finally be reached at which its influence in forcing the carbon to separate out as graphite will cease.

It is an easy matter then to start with pig iron that is gray in fracture and in which all or most of the carbon exists as plates of free graphite, and end up with an iron that is white in fracture and in which all of the carbon is combined chemically with the iron; it is a question solely of getting rid, in the air furnace, of such an amount of silicon as will accomplish this end. It thus becomes obvious that the manufacturer of malleable iron castings, by means of his air furnace, experiences no difficulty



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whatever in converting gray pig iron into white cast iron; which operation constitutes essentially the first step of the process. Many years ago it was discovered that if hard brittle white iron were surrounded tightly by an oxidizing packing, such as iron oxide in any form, and then raised to and maintained at a temperature of about 1500 degrees Fahr. for a few days, it would not only be changed into very soft and ductile iron, but some of its carbon would be removed during the interval. This constitutes the second step in the malleable iron process. Consequently, the first step toward getting soft and ductile castings in the malleable iron process, is to get very hard and very brittle castings, in which all of the carbon is combined chemically with the iron as carbide of iron, the very hardest constituent in either iron or steel. The second step is to break up this hard constituent into carbonless iron and free carbon, both of which are very soft. By the aid of photomicrographs what takes place during the second step of the process, that is, in the annealing ovens where the white and brittle castings are placed to be converted by time and temperature into finished castings, will be explained in a non-technical manner.

Fig. 1 illustrates a polished unetched section of a piece of gray pig iron, the object of which is to show the plates or flakes of graphite that separate from the metallic iron, when the silicon is sufficiently high in the iron to force the carbon thus to separate. It will be noticed that there is practically no regularity of either size or distribution of these flakes; therefore it is not to be wondered at that cast iron test-bars show great irregularity in strength, even when poured from the same ladle of iron.

Fig. 2 shows a polished section of white iron, white because its silicon content was too low to force any of its carbon to separate out as graphite. The whole of the carbon consequently remains chemically combined with the metallic iron, invariably in the proportion of 6.67 per cent. carbon to 93.33 per cent iron. This extremely hard carbide of iron is shown mostly in the white areas, but about 12 per cent. of the dark areas consists of this hard constituent also, the reason for which it is not necessary to consider for the purpose of this article.

As previously stated, carbide of iron is the very hardest constituent that can exist in either pig iron or steel, but fortunately, as already indicated, it has been discovered that if it be heated to about 1500° Fahr., for many hours, it can be split into little nodules of free carbon and a mass of practically pure iron, the former being very soft and having no strength, and the latter being both soft and very ductile and possessing high strength. An inspection of the polished sections of annealed malleable iron, Figs. 3, 4 and 5, will show that these little nodules of free carbon (the little black areas in the photomicrographs) are very uniformly distributed throughout the entire section and very uniform in size, differing in both particulars from the manner in which the graphite occurs in gray iron.

To contend that white iron castings over three-eighths of an inch in section cannot be annealed as efficiently as castings of less thickness, is to contend that a piece of white iron over three-eighths of an inch in

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Fig. 1

Fig. 2

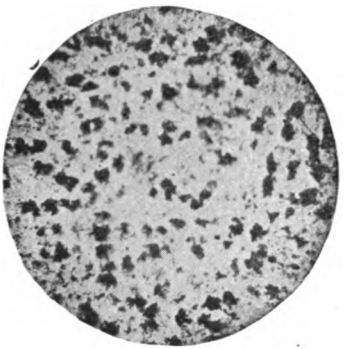

Fig. 3

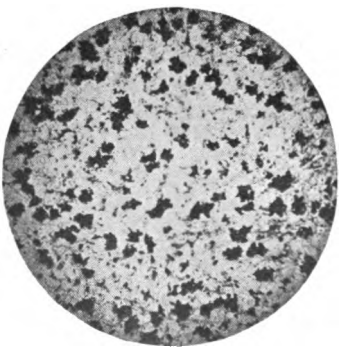

Fig. 4

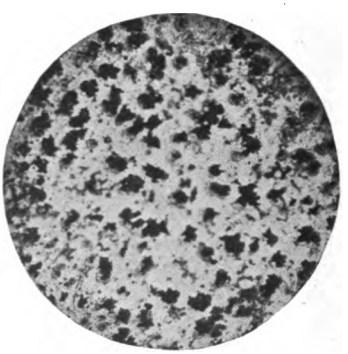

Fig. 5

section cannot be heated uniformly throughout its entire section to a temperature of 1500° Fahr. or over. This is manifestly absurd, for it must be admitted that in many different processes very ponderous pieces of steel are being heated daily throughout their mass to any required temperature. The sole precaution in any case is to see that plenty of time be

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given the operation. As it happens that in the annealing process in the manufacture of malleable iron castings, some seven days are consumed from the time the castings enter the ovens until they are withdrawn, if the breaking up of the hard carbide is not complete in the case of thick sections, this is certainly not due to lack of time to allow the piece to heat uniformly throughout. Moreover, there is no trouble whatever in maintaining the temperature of the ovens at any point under 1900° Fahr.

The direct question can now be put: What is the limit of thickness of section beyond which white iron will not be efficiently and completely annealed, that is, not have all of the very hard constituent completely replaced by little nodules of free carbon and practically pure iron? The answer is plain. Any thickness of white iron can be thoroughly and uniformly annealed throughout its section, that is not so thick that it cannot be heated uniformly throughout, and in which the whole of its carbon content exists as carbide of iron. It has been shown that whether the carbon exists as *carbide* or as *graphite,* is simply a matter of how *low* or how *high* the silicon may be in the casting. It has also been shown that the adjustment of the silicon is under the complete control of the manufacturer. If the silicon is as low as 0.30 per cent. it is possible to obtain very easily sections as thick as 6 inches, in which all of the carbon will exist as carbide of iron, although in this extreme case, to break up all of the carbide and completely replace it with free carbon and iron, a higher temperature than that normally used during the anneal is required. In sections 3 inches thick, all the carbon will exist as carbide of iron when the silicon is around 0.50 per cent., in which event neither a higher temperature nor a longer anneal than is customary in ordinary practice will be required. I have therefore placed this as the limit of thickness for efficient and complete annealing. The trade, however, does not call for malleable iron in which the sections are this heavy. The statement can be made that if the process is fully understood by the manufacturer, and he will adjust the silicon content in accordance with the heaviness of the work, no trouble from this source should exist, and none ever will.

Referring again to Figs. 3, 4 and 5, I would explain that these photomicrographs were taken from an annealed malleable section of 2 inches diameter and several inches length. The sample was cast at my request from a heat in the regular course of work. While the company makes fairly heavy castings, none of the parts approaches this sample in thickness. Still, as will be seen, the silicon in their white iron was low enough to cause all of the carbon to form carbide of iron in a 2-inch round. This sample was annealed in the oven with their own castings in exact accordance with their regular practice. Fig. 3 was photographed at a spot about ⅛ inch from the surface; Fig. 4, at a spot midway between the surface and the center; and Fig. 5 directly at the center. A close inspection and comparison of these three photographs should satisfy the most skeptical that this piece was annealed with completeness throughout, and that all of the hard carbide was broken up into free carbon and soft iron. Accompanying this sample was another of 4 inches diameter, the central part of which I found contained considerable graphite in the

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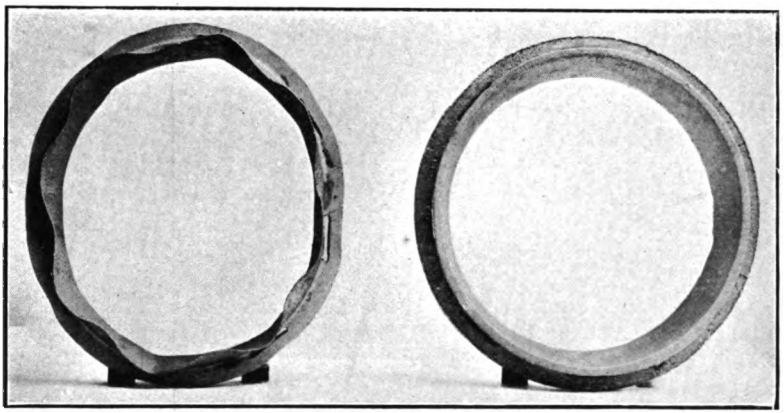

Fig. 6

form of flakes, which from their shape could be identified as having resulted from the separation of some of the carbon during the solidification of the white iron, showing that in this case the silicon in the normal mixture was not sufficiently low to have forced all of the carbon to combine with the iron, although had the silicon been somewhat lower, no difficulty in this particular would have been experienced.

### REMOVING SKIN

In connection with the oft-repeated statement that if the skin of a malleable casting be removed, and the core tested, the latter will be found to be more or less worthless and that malleable castings are strong and ductile by virtue principally of the metal in the skin, I would state there is no question whatever that the metal in the skin of well-made malleable iron is slightly superior to that which constitutes the main bulk of the casting, but only in the case of very poor malleable iron can a really great difference in strength between skin and core be noted; the poorer the malleable the more pronounced this difference. Malleable castings are not unique in this particular, for the metal in the skin of most steel castings is stronger than the central part of the casting, although not for the same reason that obtains in the case of the former. The skin of malleable castings is practically decarbonized iron, the structure being uninterrupted by the presence of any little nodules of free carbon. The structure of the core, however, differs from that of the skin, only in that throughout it little nodules of free carbon are interspersed. That in good malleable iron these little particles of free carbon do not act in a way to injure the structure to any appreciable extent, I have satisfied myself by numerous tests from time to time. To illustrate this fact, I have secured two castings of an automobile clutch ring, shown in Figs. 6 and 7. The 7/16 inch thick rim of the casting was machined down to a thickness of ⅛ inch, after which it was subjected to repeated heavy blows with a

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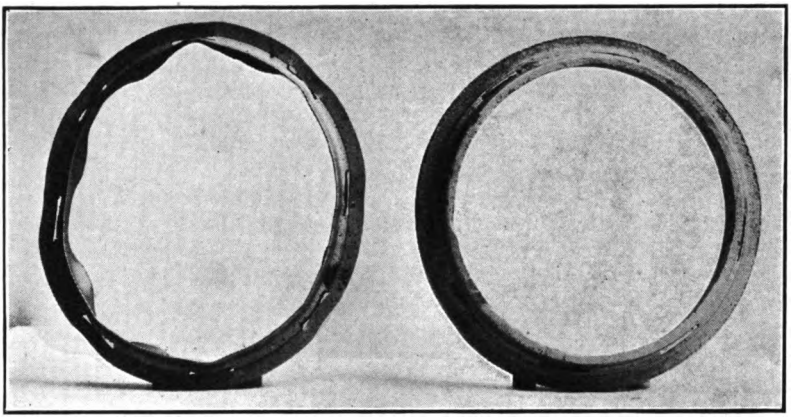

Fig. 7

hammer to test the ductility and strength of the core left after machining. It will be seen that the metal of the core, in this instance, was of great strength and ductility, able to withstand great punishment without developing cracks of any magnitude. It is most likely true that the metal in the skin of this casting was slightly superior to that in the core, but I feel confident that the difference was not great, and I repeat that in good malleable castings, while the metal in the skin is a little superior to that of the core, the difference is but slight. The photographs referred to speak for themselves.

## STATUS OF THE INDUSTRY

Some in the business have not kept pace with the advances made in malleable practice; some do not even understand the rationale of the process, or lack good manufacturing equipment. While fortunately these do not predominate, there are enough of them to throw much undeserved discredit on one of our large, important, and growing industries. I am convinced, however, that the constructing engineer has, owing to improperly designed patterns contributed unintentionally in numerous instances, to this situation. The worst offenders, however, in this particular are the engineers for the railway car builders.

If the question of shrinkage and contraction be not properly considered, if the apportioning of thick to thin sections be not adjusted in accordance with correct principles, no matter how superior may be the metal *per se,* failure is the certain outcome. The remedy should be obvious. Practically all of the makers of malleable castings have on their staff men who are very proficient in the design of patterns from which to cast malleable. Much delay, much irritation, and a great deal of injustice will be eliminated, and a much stronger casting for the same weight of metal will often be produced, when closer relationship and cooperation exist between the engineer who designs a malleable part for any particular machine and the malleable pattern-maker at the foundry. Lack of time has prevented my securing more glowing examples than

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the ones here shown, of how small need be the alteration in a pattern, in many instances, to produce good results where bad ones previously obtained. The changes shown in Fig. 8, although very slight indeed, made the difference between success and failure. The same remark holds good in the case of Fig. 9, the change producing not only a satisfactory casting but one containing less metal. In connection with the center plate shown in Fig. 10, the following are the facts: Complaint was made by the railroad that these malleable castings were failing in service. The manufacturer of the castings made the request that he be permitted to alter the patterns in accordance with what his experience indicated would remedy the trouble. This privilege was not granted. The road then decided that malleable iron castings could not be depended upon in this particular case; so it was decided to have the castings made of steel. The steel men also objected to the design of the pattern, and, as almost always happens when a change is made from malleable iron to steel, they were allowed not only the privilege denied the others, but, as can be seen by reference to the drawing, were permitted to thicken the sections by one-quarter of an inch almost throughout. That changes were made in both design and weight is soon forgotten, but not that the steel casting stood up to the work and the malleable casting failed.

## PHYSICAL PROPERTIES

As to the physical characteristics of malleable iron, I know that you are all familiar. However, at the end of this paper are reproduced some photographs of heavy malleable castings that you will acknowledge have been severely abused. They very eloquently illustrate the fact that when malleable castings are made by those who understand the process, castings that possess many valuable characteristics are produced. When toughness and ductility, ease of machining and low cost are considered, I do not know what metal can compete successfully with good malleable iron.

The tensile strength of good malleable iron will vary between about 38,000 to 56,000 pounds per square inch. When extreme ductility is desired, it is manifestly incompatible to specify high tensile strength. As in the case with carbon steel, so with malleable iron, ductility goes hand in hand with low ultimate strength; if high ultimate strength is desired, it can be obtained only by a sacrifice of ductility.

The elastic limit of good or of even indifferent malleable iron is equal to that of wrought iron and frequently exceeds it. When comparisons are made between this material and other metals, it would be more fair to consider the elastic limit rather than the ultimate strength, for it is the former upon which the engineer actually bases his calculations. The elongation and reduction of area of malleable are, of course, considerably less than of either wrought iron or soft steel. That both of these properties are high enough to impart great value to malleable castings is impressively attested by the photographs of the abused castings previously referred to.

It is the custom in plants of fair size to run various furnaces on mix-

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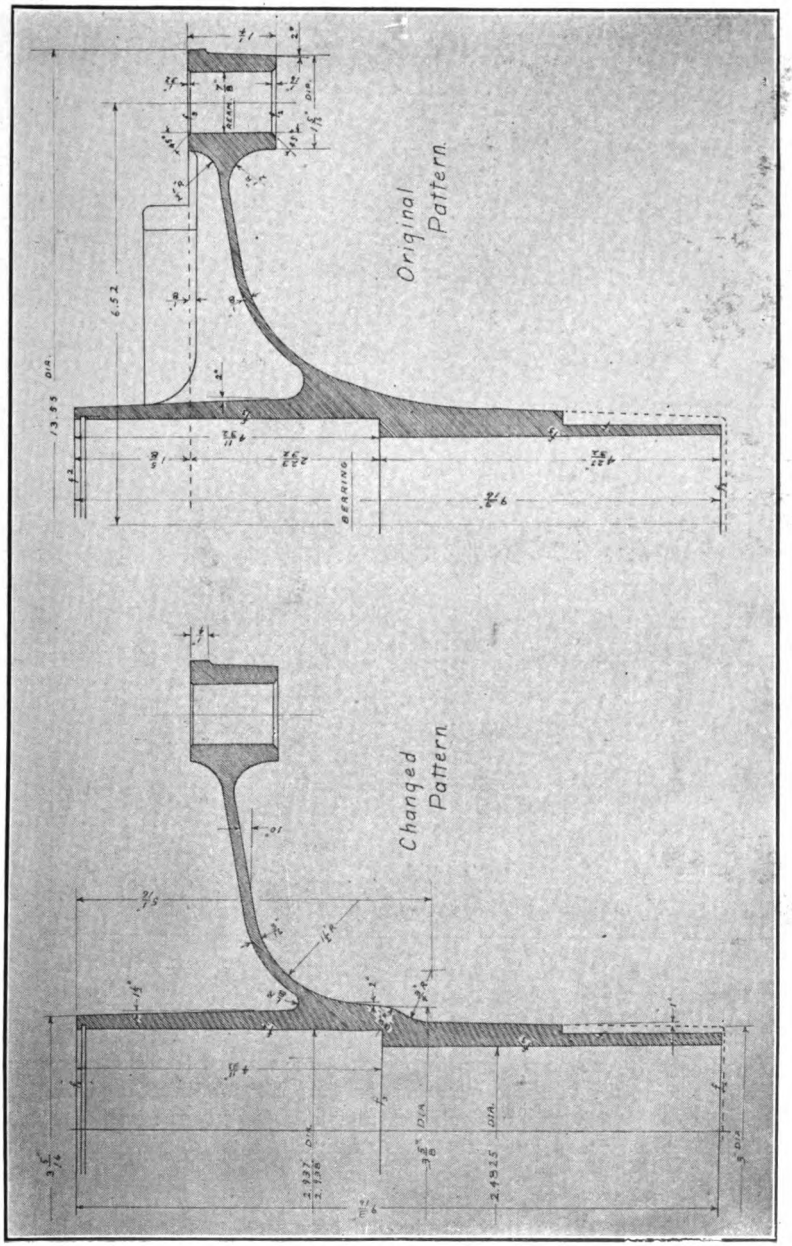


Fig. 8

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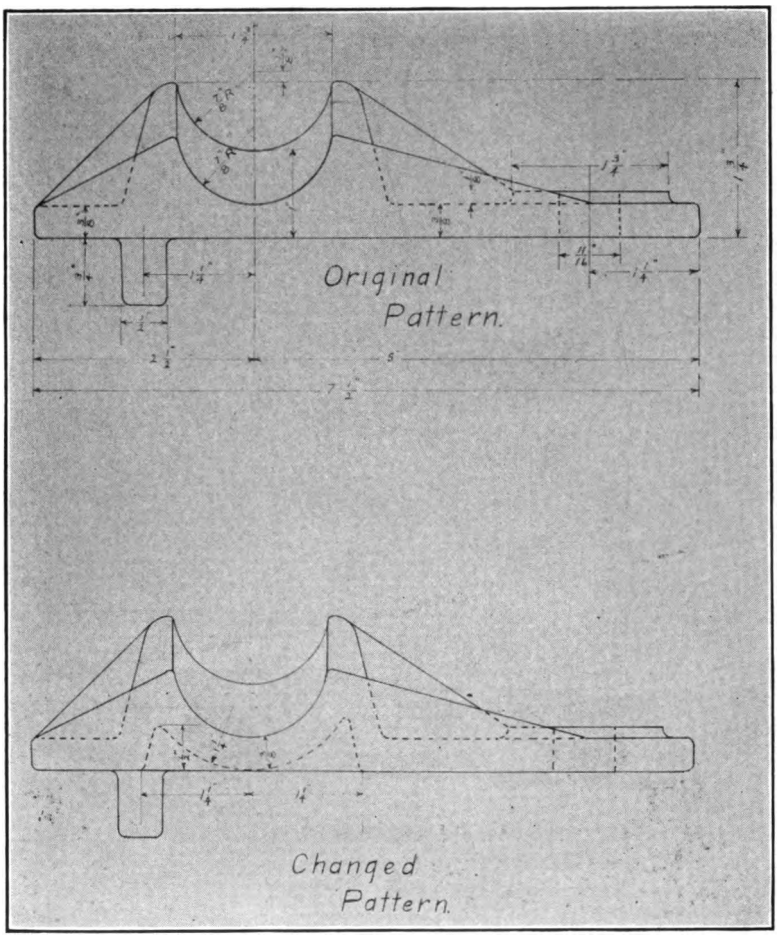


Fig. 9

tures for different classes of work. The mixture from one furnace is not as well adapted to one class of casting as to some other. If the user of the castings will only take the manufacturer into his confidence and explain the use to which any particular casting is to be put, the work expected of it in service, I know that loss of time will be avoided, and a more superior product made. Some consumers are under the false impression that for competitive reasons they should lighten their castings. This generally necessitates the introduction of more cores in the mold, the result being that the manufacturer is obliged to charge more per pound.

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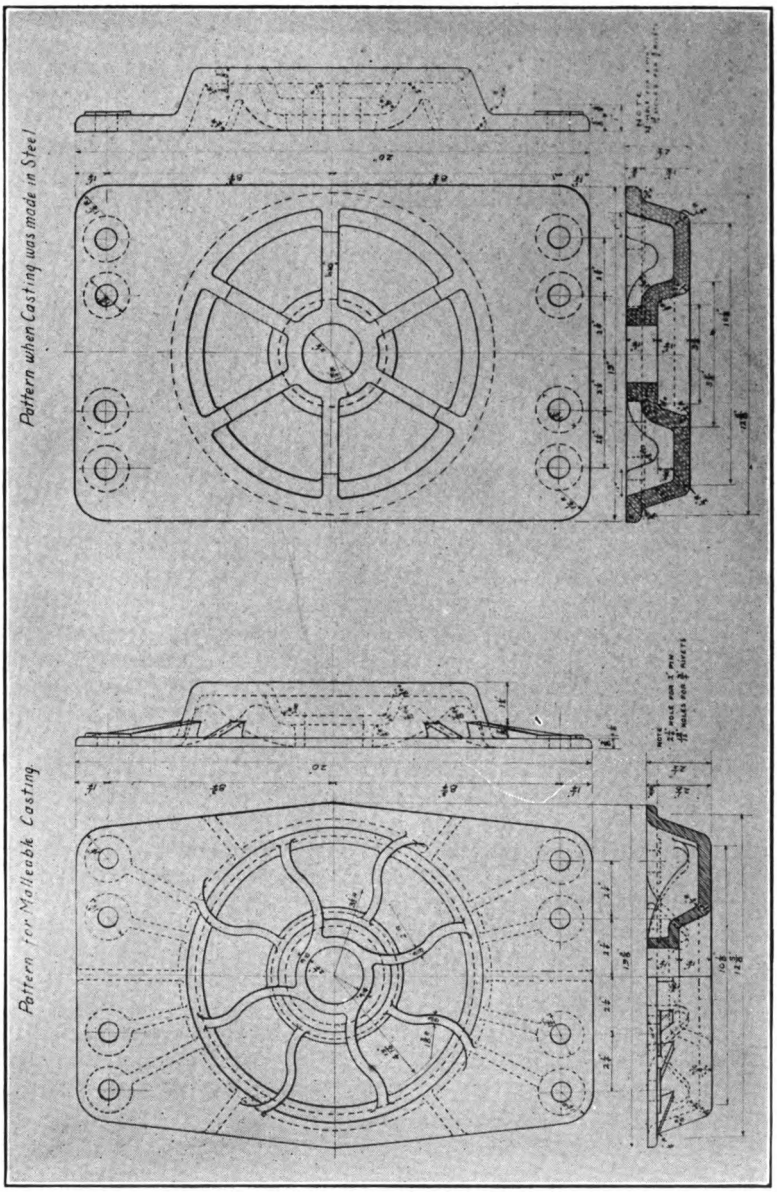


Fig. 10

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SPECIFICATION

I presume that specification is of more interest to the membership than perhaps any other one question in connection with this material. I have no desire to usurp the duties of the committee having this matter in hand, the work of which in all that has been done has been so commendable, but a few words in connection with the S. A. E. malleable iron specification will I trust be taken in the spirit in which they are intended. I believe that a mistake has been made in specifying an upper limit for silicon. As a matter of fact, it is well known that the higher the silicon in the white iron casting, provided the totality of the carbon in the casting exists in the state of carbide of iron, and all other conditions are correct, the better will be the finished product. I have shown that the manufacturer is obliged to eliminate his silicon to a point where all of the carbon will remain as carbide, and also that the extent to which he must carry out this elimination depends wholly upon the heaviness of the sections. It is exceedingly rare that he errs in getting the silicon too high, because he does not need a chemical analysis to safeguard this, as all that he has to do is to keep breaking his test sprue until he sees by the fracture that the iron is white, and that there are no particles of graphitic carbon in the fracture. He is more concerned in this particular than the purchaser can ever be, and to this extent the purchaser is protected. To specify an upper limit for silicon is about as necessary as to specify that the manufacturer shall pour his iron in the molds at a temperature sufficiently high to successfully run his castings. You can rest assured that he is going to look after the upper limit of silicon with as much fidelity as he will to be sure that the iron is hot enough to avoid trouble through misruns.

On the other hand, it would be wise to specify a limit beyond which the silicon shall not drop, because not only does the manufacturer err frequently in this direction in the making of black heart iron, but he is handicapped by having no reliable means of telling just when he is on the danger line. Analysis would take too long and the fracture gives no true indication. If the silicon is too low, a very inferior product will result, and still the purchaser if he be held to his specification can be forced to accept the castings.

The S. A. E. specification allows the manganese to be as high as 0.70 per cent. No one ever saw and no one ever will see black heart malleable iron of good quality with such a manganese content. Provided certain precautions are taken, and certain ratios made between certain elements in the product, it is possible to make a good product in which the manganese might be as high as 0.40 per cent., but to do so the manufacturer would have to be a master of his business and to know how to offset the evil effect of manganese.

The upper limit for phosphorus given (0.20 per cent.) is all right, but it is actually the extreme upper limit that should be tolerated. The Society for Testing Materials allows 0.225 per cent. as an upper limit for phosphorus, but this is by far too high. I feel very confident that a good product could not be obtained if this limit were reached.

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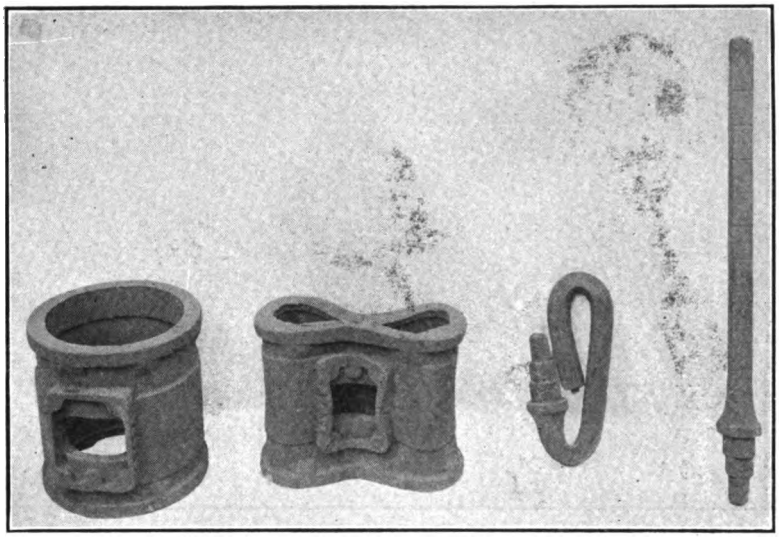
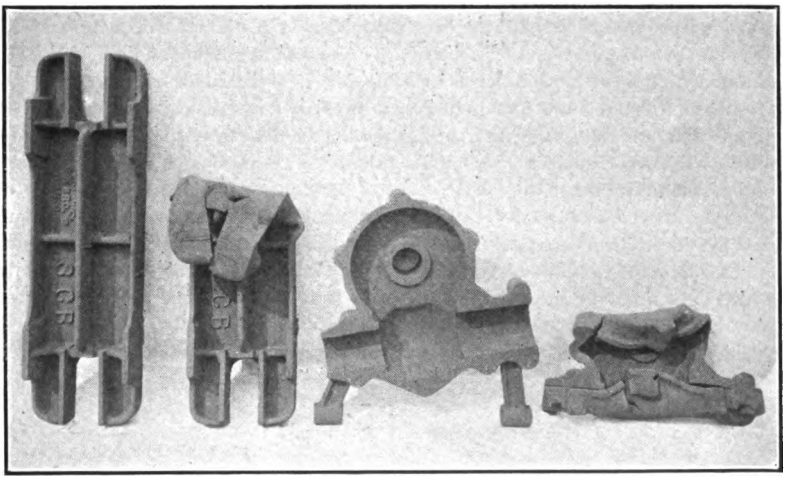


Abused Castings



Abused Castings

No mention is made in the S. A. E. specification as to carbon content, or the permissible amount of combined carbon tolerated; nor is any limit placed upon the allowable amount of total carbon.

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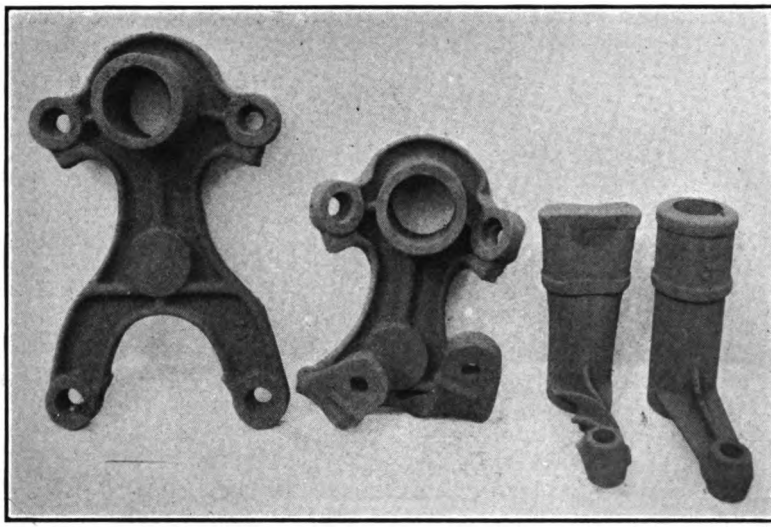

Abused Castings

## DISCUSSION

HENRY SOUTHER.—Mr. President, as chairman of the committee having this matter in charge, I wish to thank Mr. Touceda for the information he has given. There is too little information available of the malleable industry, and we are always looking for help. The committee will be the first to seize upon the help given by Mr. Touceda in this paper. We hope that any one who has specialized in an art, as Mr. Touceda has in this, will write such a paper. It will advance the work of the Society to a splendid degree.

PRESIDENT MARMON.—I think it is obvious to even a layman that some people have been successful in building what we used to call in derision malleable iron cars that have stood up for many thousands of miles, while other people who thought they used better material, but relied on malleable iron for very minor parts, were always in trouble. There is evidently a great deal of importance in whether you get good malleable castings.

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# A NEW TENSILE TEST PIECE AND HOLDER

By K. W. ZIMMERSCHIED
(Member of the Society)

The standard 2-inch tensile test piece of this Society, when made from steel with an elastic limit of 125,000 pounds per square inch or less, and when pulled as made, presents no particular difficulty. With the increased demand for accurate data on steels of much higher strengths, however, we have found this form difficult to use, for a number of reasons.

It has often been necessary to investigate the properties of a given steel under various heat treatments. In this case, it often happens that the stronger pieces of a series are too hard to machine without using heroic methods; threading of the ends becomes especially difficult. If, on the other hand, the test pieces are first made in the soft state and then treated, instead of treating the ¾-inch bar and machining afterward, a new set of difficulties arise.

First, the quenching of finished pieces generally sets up high local strains in the threaded ends, especially when water quenches are employed. This can be obviated to some extent by protecting these threaded ends with a coating of asbestos, silicate mixtures, or the like. Care must be taken, however, not to hold the butts too soft, or they will be too weak to withstand the load necessary to break the test length. In any case, oxidation of the threads will take place unless considerable precaution is taken to prevent it, and the resulting scale then makes it necessary to clean out the threads if close fits in the holder are to be obtained.

Aside from machining difficulties, however, warpage of the test piece during heat treatment is very troublesome. Suppose that a specimen is made up with twenty to thirty thousandths excess stock left on the diameter, to be ground after treatment. This specimen is almost certain to warp or bow up more or less on quenching—grinding will straighten out the test length, but the butts will still be out of line, and if the specimen is pulled in the ordinary holders, the loading is certain to be more or less eccentric.

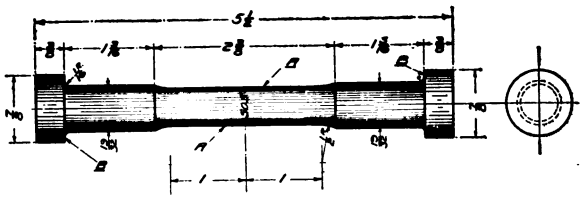


Fig. 1.

It was to obviate all these difficulties that the test piece shown in Fig. 1 was designed. This is made up from a 7-8 inch or 1 inch round



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bar in the soft state, leaving .030 to .040 inch on the test length diameter, and on surface "B." The advantages of this form from the viewpoint of machining cost is quite evident. Again, no ordinary heating or quenching operation will affect the specimen unfavorably, because of the absence of threads and of the fillets at all changes of section.

After treatment, grinding of the test length and of the surface "B" with the same wheel will insure that, no matter how badly it is warped, the plane of load application will be normal to the axis of the specimen, and uniform in intensity, and a straight line pull will result.

There are still minor irregularities in the testing machine to take into account. In order to care for these, and to provide a rapid and convenient method for changing test pieces, the holders shown in Figs. 2 and 3 were devised. With a few explanations these figures become almost self-explanatory.

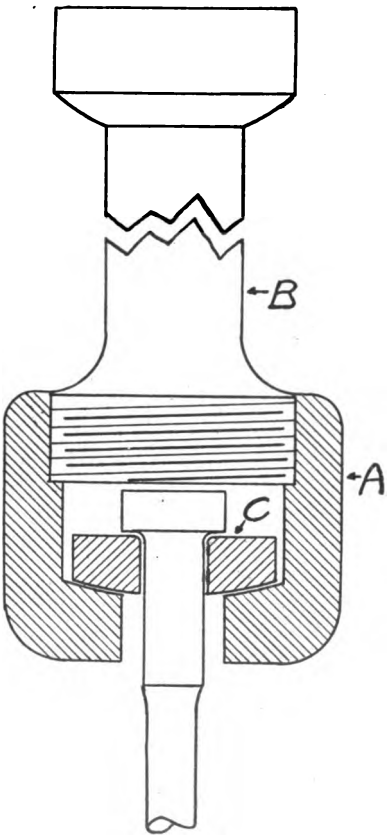


Fig. 2.

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"A" is a sort of socket nut, which screws on to the end of the spherical headed bolt "B," which latter bears in standard blocks in the test machine heads. The hole in the socket nut allows of slipping the butt of the test piece through. The split ring "C" is snapped on to the shank and held with a rubber band, the nut is then screwed on to the main bolt. The operation is repeated on the bottom nut, and the piece is set ready to test.

As noted, the heads of both bolts "B" are ground in their sockets to a spherical bearing. The split rings are also ground to a spherical bearing in the socket nut—thus there is an unusual linkage employed, which can be relied upon to correct whatever small irregularities may exist in the machine or in the test piece.

It is also found that the fit between specimen and holder is so accurate and unyielding that extensometers may be applied directly to the holders with no commercial error. This is illustrated in the photograph; the saving of time necessary to apply ordinary extensometer clips is a

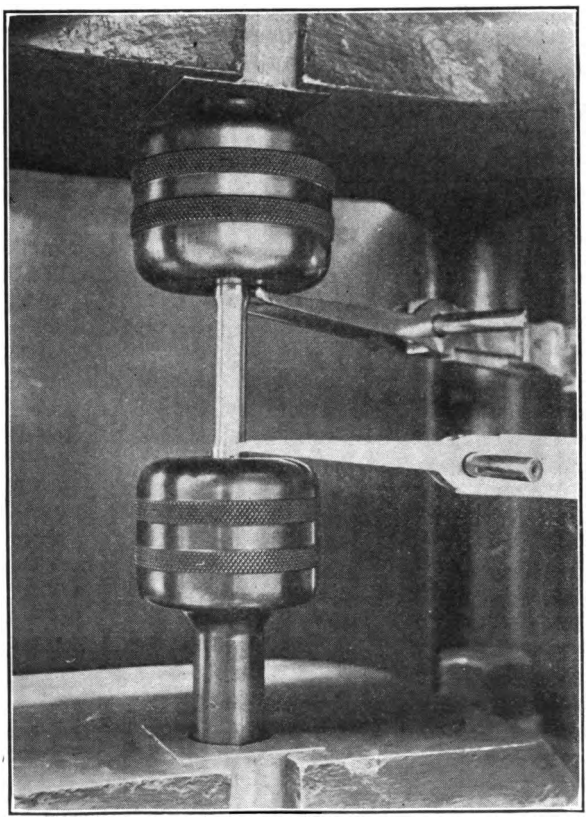

Fig. 3.

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considerable advantage. It goes almost without saying that these holders are made from heat treated alloy steel of high strength; in them test pieces have been broken at maximum strengths of over 300,000 pounds per square inch.

Using this fixture on a large number of test pieces we find a very large percentage of the fractures showing perfect cups and cones, or stars perfectly centered—none bear evidence of a side pull. The test results are also more regular, duplicates agreeing considerably more closely than when using the old test pieces and holders.

In conclusion, the writer would confess that the fundamental ideas in this note are based upon the constructions used in well-known German testing machines. The advantages in this new form of holder are chiefly from the standpoint of simplicity in manufacture and use. For valuable aid in their design, the writer's indebtedness to Mr. Frank Burton, Concrete Commissioner of the City of Detroit, is hereby acknowledged.

## DISCUSSION

PRESIDENT MARMON.—Professor Zimmerschied has described quite an interesting refinement.

HENRY SOUTHER.—Without knowing it our laboratory in Hartford has been working along similar lines and has evolved a specimen very much like that described. I want to ask Professor Zimmerschied whether the fillet between the largest diameter and the one next to it is sufficiently generous to permit the treatment of very hard steel without the danger of rupture in the angle? I favor a very generous fillet for very high carbon or very hard steel.

PROF. K. W. ZIMMERSCHIED.—I can only say in answer that so far we have had but one failure of the type mentioned; that is out of a large number of test pieces with elastic limits as high as 240,000 pounds per square inch, only one failed in the fillet and that one was probably more lacking with respect to heat treatment than with respect to the size of the fillet. We could not make this fillet larger and preserve an adequate bearing surface without making the stock larger than 7-8-inch diameter, which we desire to hold as a maximum.

G. F. FULLER.—I think Professor Zimmerschied's work in developing the test piece is of more importance than the average engineer appreciates. Some two years ago our laboratory determined that it was useless, practically, to try to get any accurate information by tensile tests on pieces in a condition so hard after treatment that they could not be machined, on account of the exact feature that Professor Zimmerschied has touched upon, that is to say, the warping of the specimen. Our practice has been for two years to grind; leaving the specimen oversize in the case of any material too hard to machine after treatment and grinding to size. Of course, that prohibited cutting the threads, because of the fact that, as Professor Zimmerschied stated, they often flake off. We developed almost exactly the same thing Professor Zimmerschied has shown, with the exception that we used, in a three-column Olsen tensile testing machine, an internal nut. We split the nut and simply clamped the two sides

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of it on to almost exactly the same holding head as Professor Zimmerschied shows. This, of course, obviated the necessity of cutting any thread whatever. Using the internal nut in the pulling bar, the bar itself has a swivel to accommodate any inequality in the machine. We found a great difference, as Professor Zimmerschied has indicated, in the accuracy and consistency of the results due to that practice.

E. S. FOLJAMBE.—Is there any committee which at the present time is looking into the matter of the test specimen or has it been decided that the test specimen adopted is sufficiently good?

HENRY SOUTHER.—As I understand, so long as our committee exists we are never through. The test specimen is one of the items that we have been watching quietly. Let me go back a bit. The Society for Testing Materials adopted a standard test specimen, for a very proper reason. It was a very good test specimen for the steels in common use at the time it was adopted—structural steels, bridge steels, gun tubes, propeller-shafts and all that sort of thing; the elastic limit being not excessively high. Along comes the automobile industry, upsetting all precedents and attempting to use and test steels that were rarely tested before. That is the reason this new test specimen is gradually crowding itself forward. You cannot stop it, whatever sort of a test specimen we may adopt. If a better one is needed, it will be found; our committee will seize upon that specimen and make it standard if Professor Zimmerschied will permit, just as soon as we think it is worthy of becoming a standard or recommended practice. If I am wrong in that, I would like to be corrected. That is my view of the situation.

E. S. FOLJAMBE.—That was my idea.

PRESIDENT MARMON.—The Chair would like to ask Professor Zimmerschied if this test specimen is not considerably cheaper to make than the standard one for any material?

PROF. K. W. ZIMMERSCHIED.—I would say that where steels that are hard are concerned, this test piece is much cheaper to make on account of the fact that it avoids the necessity of cutting threads in the ends. On soft steels it probably is not much cheaper to make than a threaded specimen, but the subsequent heat treatment of the latter presents the difficulties which have been mentioned in the paper.

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# SOME FACTORS PERTAINING TO MOTOR DESIGN

By Claude E. Cox.

(Member of the Society.)

## INTRODUCTION

This paper deals with one or two of the more important problems encountered in modern motor building, starting with the first inception in the mind of the engineer, following through the designing, the building of the experimental motor, and ending with the quantity production in the factory. These problems are treated more than a practical standpoint, using whatever experimental data are available. Complicated mathematical formulæ are conspicuous by their absence.

The progress of the engineer in his work of designing a motor can be likened to that of the surveyor, who starts out to survey a triangular piece of land of large dimensions. He works for a time on one side of the triangle until he has measured the required distance, when he starts from that point in a different direction and again measures the required distance. He then turns through a given angle and measures the required distance for the third side. If his work is good he arrives at the starting point and thereby closes the triangle. The first side of the automobile engineer's triangle covers the design, the strength of materials, the balancing of the moving parts, etc. After this is completed the second side of the triangle represents the building and testing of the experimental motor. After this is completed, the third side is represented by the quantity production. If the motors coming through the factory are well-balanced, quiet, efficient and develop the required power, the triangle is closed and the engineer can consider his work well done.

## DESIGN

The brake-horsepower desired at a given speed is usually the starting point of motor designing. Occasionally a car of a given wheelbase and weight is the starting point. The ratio of horsepower to weight varies from 50 to 125 pounds per horsepower. It is not entirely an engineering problem and will not be considered in this discussion. The concrete example used to illustrate some of the engineering problems is a thirty-five-horsepower six-cylinder motor. This means a motor that can be honestly listed in a catalogue as a thirty-five-horsepower motor and will equal in performance all motors of this capacity, either four or six cylinders.

What is an honest rating is the first question encountered. The three methods of rating most commonly used are: First, the A. L. A. M. horsepower formula; second, the horsepower developed at the speed at which the car is usually operated, say 20 miles per hour; and last, and decidedly not least, the maximum horsepower developed at the best speed obtainable, which may be 1,800 or 2,800 r.p.m. The last is manifestly not a method that can be standardized, the second is not much better because gear ratios and wheel diameters must be considered, and the first, which takes piston



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speed as the fixed quantity, is manifestly unfair to the long-stroke motors, particularly in view of some of the high speeds obtained by long-stroke motors abroad. As a substitute for the above methods, let us consider piston displacement and revolutions per minute and see what results can be obtained. A cubic inch of piston displacement means a certain volume of explosive mixture taken in every other revolution, ignited and part of its energy expended in useful work; the greater number of revolutions the more work is delivered by each unit of piston displacement. The working value of a unit of piston displacement may be affected by

1. Design of the motor.
2. Size of motor, i.e., total piston displacement.
3. Speed of the motor.
4. Proportion of bore and stroke.
5. Number of cylinders.

A careful study was made of a large number of tests* and the following conclusions were reached:

I. Motors made by reputable manufacturers and which have a good record for performance give practically the same work per unit displacement.

II. Motors ranging in size from 3¾ x 3¾ to 4½ x 5¾ and 5 x 5 showed no difference traceable to the size.

III. The work per unit displacement varies consistently with the speed in all the cases considered.

IV. Proportion of bore and stroke shows a marked effect. The long-stroke motor shows a marked superiority over the square motor.

V. Only long-stroke six-cylinder motors were available. These showed better results than the four-cylinder square motors, and not as good results as the four-cylinder long-stroke motors. This difference was due, evidently, to the proportion of bore and stroke and not to the number of cylinders.

In compiling the figures from the tests the motors were divided into three classes:

B. Square Motors,
C. Six-Cylinder Motors,
D. Long-Stroke Motors,

and curves plotted to correspond. Inasmuch as the torque is the first figure to be derived from the actual scale readings of the dynamometer, pounds-feet torque for one cubic inch effective piston displacement is plotted first. It is derived by dividing the torque of the motor by the piston displacement of one cylinder, multiplying by the number of cylinders and dividing by two in order to get the cubic inches actually working during one revolution. Call this value unit displacement torque, represented by U.D.T., then

$$\text{U.D.T.} = \frac{8\,T}{\pi\,D^2\,N\,S}$$

*The curves shown in this paper were made up from five summary sheets, which covered about 1500 results, which were computed from about thirty standard motor test curves and thirty accompanying data sheets.

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$$= 2.546 \frac{T}{D^2NS}$$

Where T = Torque of motor in pounds at 1 foot radius.
D = Diameter of cylinder in inches.
N = Number of cylinders.
S = Stroke of motor in inches.

This gives a figure for the speed at which the torque was taken and when calculated for different speeds gives a curve as shown in Chart I. With these figures available it is easy to plot a unit displacement horsepower U.D.H.P. curve by the following formula:

$$\text{U.D.H.P.} = \frac{\text{U D T} \times \text{R P M} \times 2\pi}{33{,}000}$$

$$= \text{U D T} \times \text{R P M} \times 0.0001904$$

The curve derived by this method is shown in Chart II.

In the same way unit displacement fuel consumption, U.D.F., is derived by the formula

$$\text{U.D.F.} = \frac{\text{(Gasl. lbs. per Hr.)}\ 8}{\pi D^2 N S}$$

$$= 2.546 \frac{\text{Gasoline lbs. per Hr.}}{D^2 N S}$$

as shown in Chart III.

Likewise the unit displacement friction loss, U.D.F.L., is determined by the formula

$$\text{U.D.F.L.} = \frac{\text{Friction H P} \times 8}{\pi D^2 NS}$$

$$= 2.546 \frac{\text{Friction H P}}{D^2 NS}$$

and is plotted in Chart III.

With these tables it is easy to determine the piston displacement required for a given horsepower at a given speed. Take 35 H.P. at 1,200 R.P.M. In Chart II we find the U. D. P. to be .241 at 1,200 R.P.M. Dividing 35 by this gives 145 cubic inches effective piston displacement necessary. This means 290 cubic inches for all cylinders and for a six-cylinder motor we would divide by 6, which would give 48.3 cubic inches for one cylinder.

The charts show the advantage of a long-stroke motor, but the proportion is arbitrary. For this case assume a bore to stroke ratio of 1 to 1.5.

We then have:

$$48.3 = \frac{\pi D^2 S}{4}$$

Since $S = 1.5\,D$

$$48.3 = \frac{\pi D^2 \times 1.5}{4}$$

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$$D = \sqrt[3]{\frac{4 \times 48.3}{\pi \times 15}}$$

$$= \sqrt[3]{41}$$

$$= 3.448'' \text{ diameter}$$

$$S = 5.172'' \text{ stroke.}$$

Taking even fractions of an inch we would have a 3.5″ bore × 5.25″ stroke with an effective piston displacement

$$\frac{3.5^2 \times \pi \times 5.25 \times 6}{8} = 151 \text{ cu. in.}$$

or 4 per cent. greater than required to give 35 B.H.P. at 1,200 R.P.M.

It is now possible to plot a typical curve sheet showing the brake-horsepower, fuel consumption, friction loss and torque, which should check very closely with the actual performance of the motor when built. If the actual results are less than the figures given some feature of the design or construction must be inferior to the average motor.

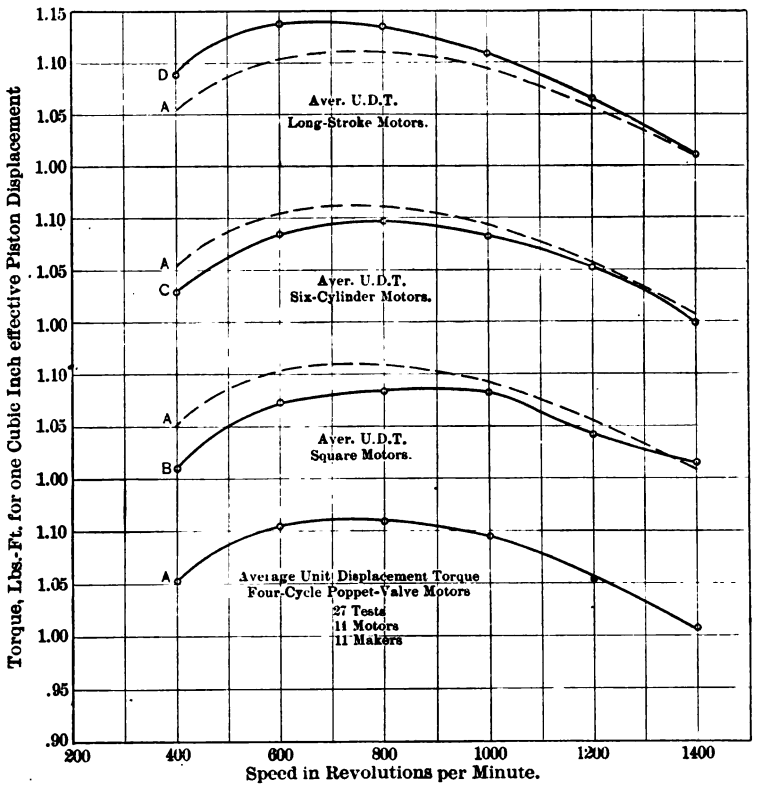


Chart I.

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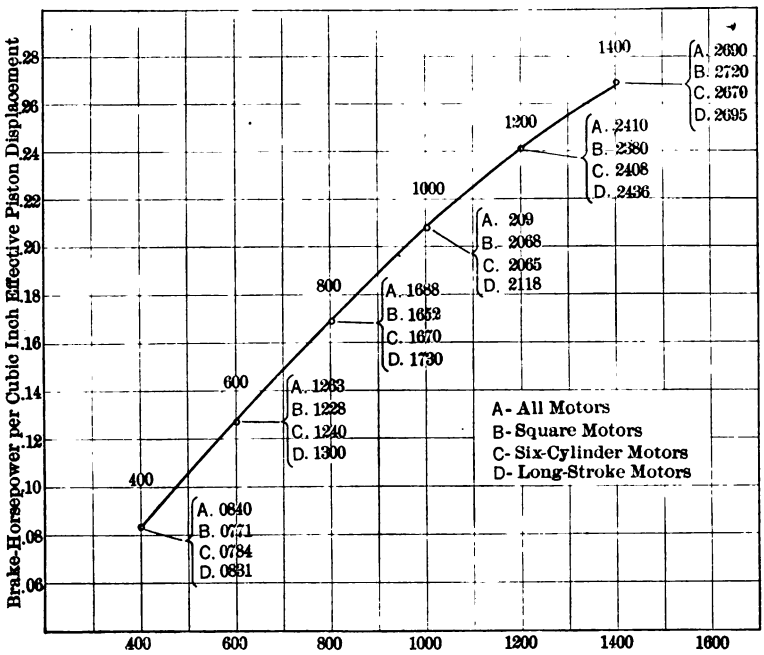


**Chart II.**

With the size of the motor determined the many problems of material, strength of parts, balancing, etc., must be solved. Of these the correct balancing is very important and not well understood. The unbalanced forces in a motor are broadly divided into three classes:

1. Unbalanced forces due to unequal acceleration of oppositely moving pistons. These forces can never be eliminated, but can be reduced by making the reciprocating parts lighter. A great deal of work has been done by various mathematicians on the balancing of the reciprocating parts. The results all show that as long as the reciprocating parts have weight, there will be unbalanced forces. When the parts are light the forces are small and as the weight increases the forces increase. This is shown in practice by the excellent balance of some of the extremely long-stroke motors made abroad. Close inspection shows the pistons and connecting-rods to be extremely light. Some of these motors will run over 3000 R.P.M. with practically no vibration. Light parts mean good material and good workmanship and higher cost of manufacture.

2. Unbalanced forces due to unequal weights of reciprocating parts. These forces can be practically eliminated by carefully weighing the parts. No matter how heavy or how light

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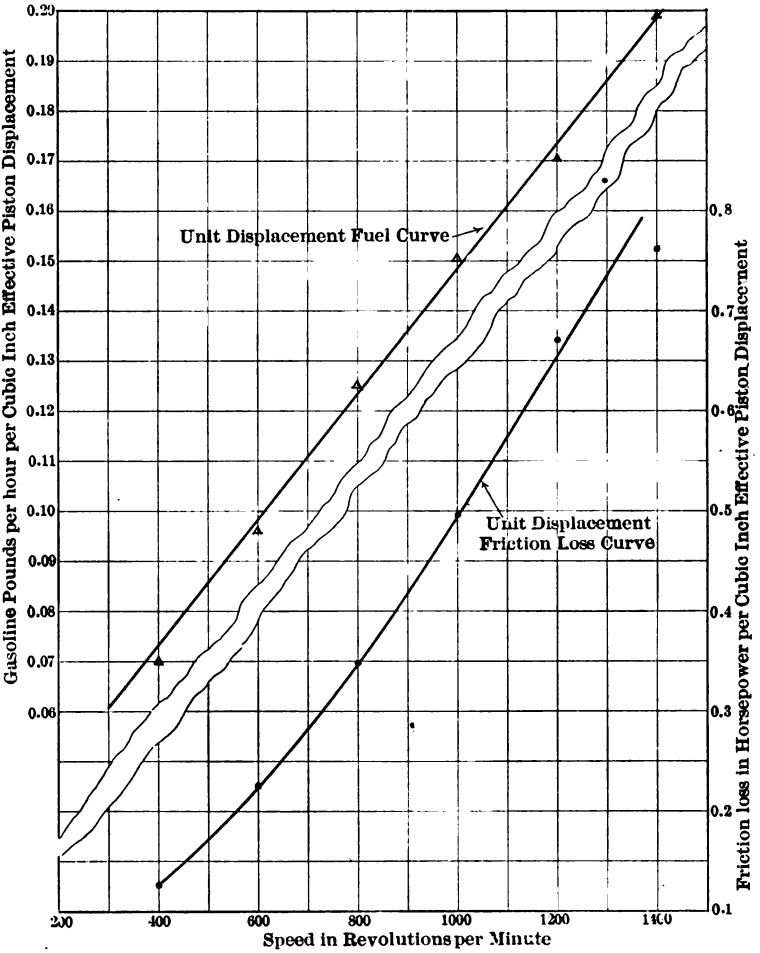


Chart III.

these parts are, they must all be of the same weight. A difference of one-quarter of an ounce will produce a marked vibration at high speeds. So the importance of carefully weighing the parts cannot be over-estimated.

3. Unbalanced forces due to the incorrect balance of the rotating parts. This is a very fruitful source of trouble due to incorrect design or lack of care in the factory.

Six-cylinder crankshafts present the greater number of problems and are considered in the following discussion. Four-cylinder shafts can be treated in the same way and are much simpler. The most common error

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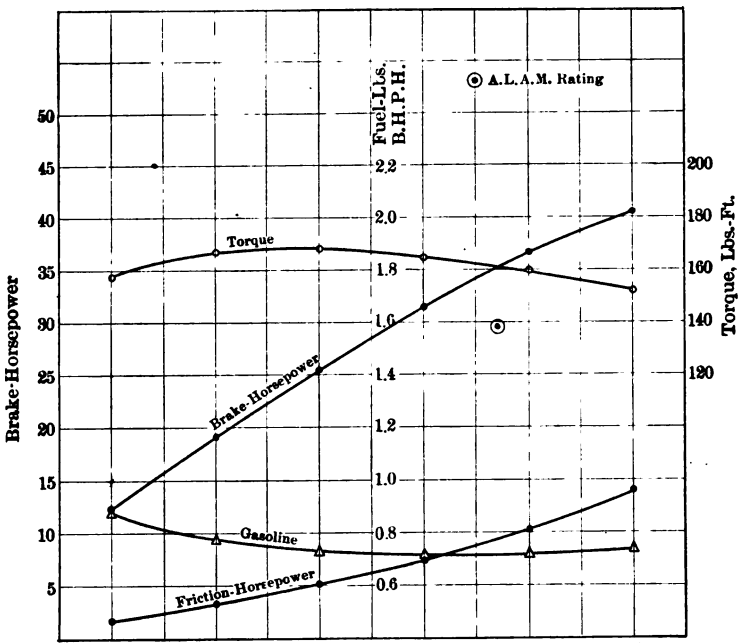


Chart IV.

in the design of four-cylinder shafts is to make the last arm next to the flywheel heavier than the others, and then omit to put in an equivalent weight placed symmetrically on the other end.

A six-cylinder diagram is shown in Chart V. By eliminating the parts which are of equal weight and placed symmetrically about the axis and reference planes, the problem can be simplified. The line bearings (1) being machined and symmetrical about the axis are balanced within themselves and can be eliminated. The three crank-arms (5) on the right side of the plane *C* are the same distance from the plane as the three on the other side; they are also spaced equally about the axis of the shaft and will therefore balance each other at any speed. They can therefore be eliminated. The six crankpins (2) can be paired off in the same way and be eliminated as they balance each other.

This leaves the two diagonal arms *L M N* connecting the first and second, fifth and sixth crankpins, and the counterweight *O* to be accounted for. It is necessary to make a new diagram for these, leaving out the parts that have been eliminated. The greatest variation in design is in these parts. There are three usual types:

L. Straight Arms connecting the two pins.

M. Diagonal Arms running to the center.

N. Complete Discs.

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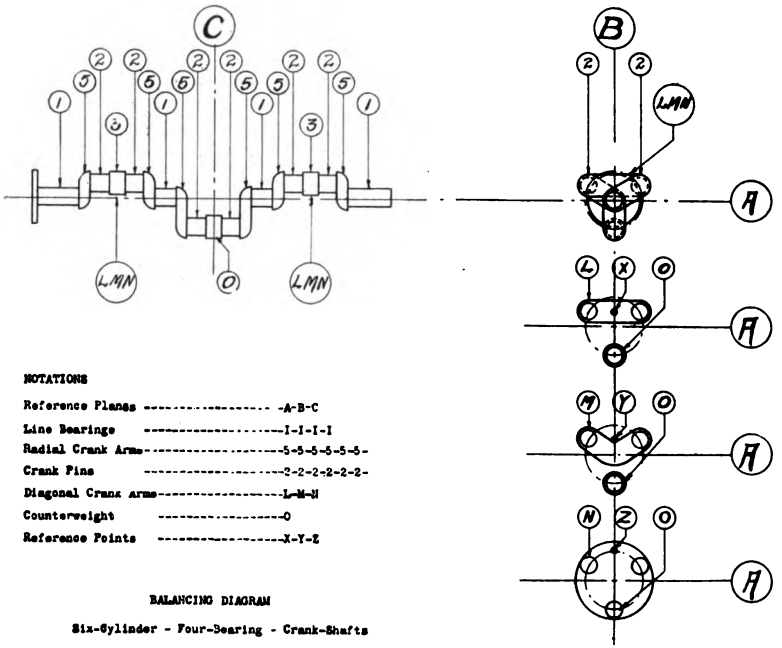


Chart V.

All three types can be balanced perfectly at any speed.

Consider the diagonal arms *L*. They are symmetrical on the right and left of the plane *B*, and can be treated as if concentrated at point *X*. They can therefore be balanced by the proper weight placed at *O*. They are equidistant from the plane *C*, so a single weight at *O* will balance the two arms perfectly at all speeds.

Consider the radial arms *M*. They are symmetrical on the right and left of the plane *B* and their action is the same as if concentrated at some point *Y*. So they can be balanced by the proper weight at *O*. They are also equidistant from the plane *C* and can therefore be balanced by a single weight at *O*.

In these two cases it is necessary to add a counterweight at *O*.

Consider the disc *N*. If it is a true disc it is balanced perfectly within itself and we will then have to add weight on each disc at some point *Z* along the line of the plane *B* in order to balance the weight of the cylinder *O*, which connects to two center pins. This design can be perfectly balanced at all speeds.

With the three forms equally well balanced, the one with the least weight and making the stiffest shaft will be best.

The discs *N* add greatly to the weight of the shaft and do not add to its stiffness. Therefore they are not desirable.

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The radial arms *M* are not the shortest connection between the two crankpins and would require to be heavy in proportion.

The diagonal arms *L* are the shortest connections between the two pins and therefore have the least weight for a given stiffness. They are accordingly the most desirable form, being subject, of course, to modifications necessary in forging and forming the shaft.

This discussion treats of the four-bearing shaft. The usual design of the seven-bearing shaft is perfectly balanced. The three-bearing shaft has the same problems as the four-bearing.

## THE EXPERIMENTAL MOTOR.

Consider now that sufficient time has passed to complete all of the drawings, patterns, castings and machine work and that the parts are ready to assemble. This is the last chance the engineer has before the tests are made and he should be on hand. The pistons must be weighed carefully and balanced. The connecting-rods must be balanced by weighing the ends separately. This will give the correct weight for the part that is considered as rotating with the shaft and of the part that is considered as moving with the piston. The crankshaft must be balanced in a running balance machine.

With these points checked up and noted for future reference, the motor is ready to assemble and test. After sufficient running in, so that the motor can be run under power, the engineer should be on hand with the typical curves which were plotted when the motor was designed. After the usual amount of carbureter adjusting, valve grinding, etc., a preliminary test is made and the results plotted in the same manner as the typical curves above referred to. It is an anxious moment for the engineer when he begins to compare results. There may be serious differences which must be eliminated. The location and correction of an error in design or construction require more skill than is usually put into the design. A broad experience may supply some parallel case which will locate the trouble at once; otherwise the problem will have to be solved by the process of elimination. A complete motor test may be necessary to locate the trouble. Where there is no trouble a complete test may help to make a good motor better.

The outline shown in Chart VI covers a complete test; it shows the results desired as they are generally specified, the units in which these results are expressed, and the observed data necessary to complete the results. A similar outline is used in steam engine tests, boiler tests and large gas engine tests.

Some available experimental data on mechanical efficiency and volumetric efficiency were used in plotting the curves shown in Chart VII. The data being limited, this table is not so conclusive as Chart IV.

Very few data are available on combustion efficiency and thermal efficiency, so it is not possible to plot curves over a full range of speed. The results are usually taken at one or two speeds; therefore they are comparable in a general way. Practically no data are available on combustion

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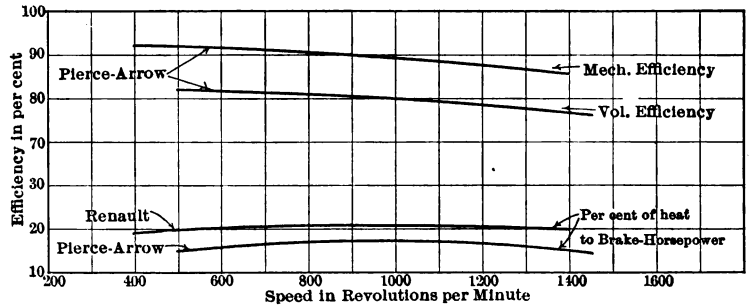
| Results Desired | Results Expressed in | Observed Data |
|---|---|---|
| **Routine Test** | | |
| Torque | Pounds at 1 feet Radius | 1 Scale Reading |
| Horsepower | | -1- |
| Fuel Consumption | Pounds per B.H.P. Hour | 2 Pounds |
| Spark Position | Degrees of Crank Angle | 3 Degrees |
| **Mechanical efficiency** | | |
| Friction loss | Horsepower | 4 Scale Reading |
| Ratio Friction loss to Total Power | % | 1 & 4 |
| **Volumetric Efficiency** | | |
| Volume of Air used | Cu. ft. per min. | 5 Cu. ft. Air |
| Compression Pressure | Pounds Pressure - gage | 6 Gage Reading |
| Ratio Vol. to Piston displacement | % | 5 |
| **Combustion Efficiency** | | |
| Volume of Air used | Cu. ft. per min. | 4 |
| Fuel used | Pounds per min. | 2 |
| Ratio Fuel to Air | By Weight | 2 & 5 |
| $CO$ & $CO_2$ in Exhaust | % | 7 Exhaust Analysis |
| Ratio burned to Total Fuel | % | 2 & 7 |
| **Thermal Efficiency (Heat Balance)** | | |
| Heat of burned Fuel | Considered as 100% | 2 & 7 |
| Heat to Brake Horsepower | % of Heat of burned Fuel | |
| Heat to Friction loss | % of Heat of burned Fuel | |
| Heat to Cooling Water | % of Heat of burned Fuel | 8 Wt. & Temp. of Water |
| Heat to Exhaust | % of Heat of burned Fuel | 9 Vol. & Temp. of Exhaust |
| Heat to Direct Radiation | % of Heat of burned Fuel | By Difference |
| Total equals | 100% | |

Chart VI.



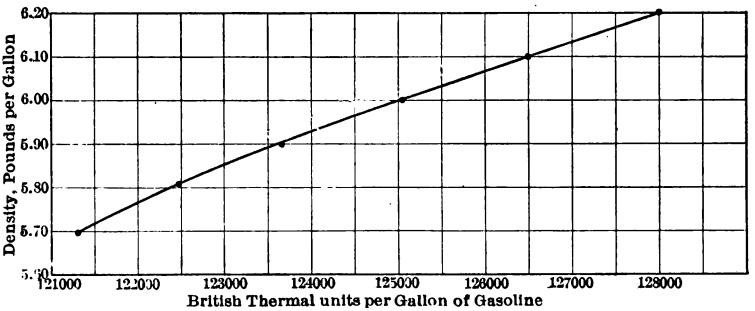




Chart VII.

efficiency; accordingly it was necessary to resort to mathematics in order to get some hypothetical figures.

A complete test as outlined, carefully made and compared to the unit displacement and efficiency curves, shows at once the cause of the trouble or the points wherein the motor can be improved. If the volumetric effi-

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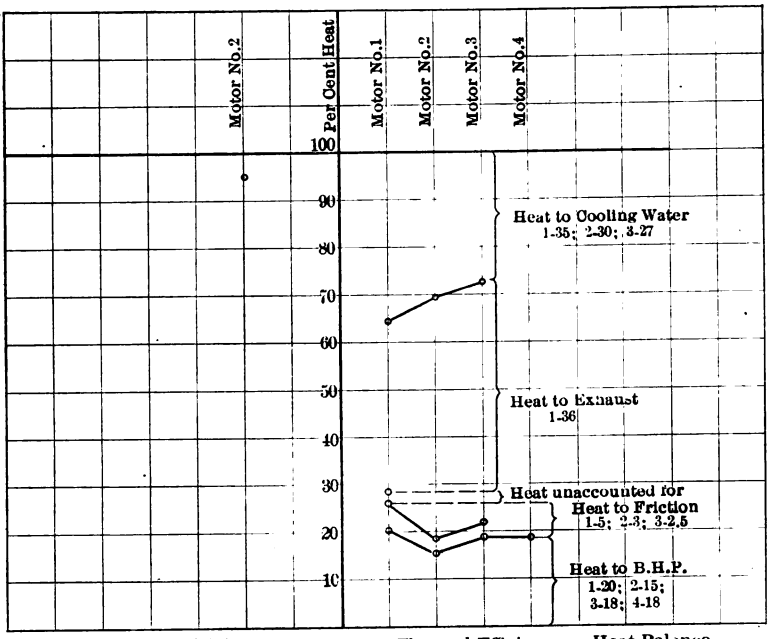


Chart VIII.

ciency is low, the inlet passages are obstructed or the valve timing is at fault. Running a test with the carbureter and intake manifold off will show which it is. If the fuel consumption is high, the exhaust gas analysis will show it in the combustion efficiency. In fact, the complete test gives all the data necessary to correct such defects as low brake-horsepower, high fuel consumption, difficulty in cooling, etc. The engineer is never sure of his work until such a test has been carefully and accurately made.

In compiling the data given above several discrepancies were encountered. The most noticeable was the apparent confusion of specific gravity and Baumé readings as applied to gasoline.

The specific gravity of gasoline is the ratio of the weight of a cubic inch of gasoline to the weight of a cubic inch of water. Gasoline being lighter than water, this ratio is less than one.

Baumé readings are based on two scales, one for liquids lighter than water and the other for liquids heavier. To convert Baumé readings to specific gravity for liquids lighter than water the formula

$$\text{Sp. G.} = \frac{140}{130 + \text{Degrees Baumé}}$$

is used. Committee reports wherein the specific gravity of gasoline is given as 64, cause confusion. Reference to the S. A. E. Data Book,

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page 23b, Vol. II, shows the Baumé reading corresponding to a specific gravity of 64, to be 88. It is improbable that a motor would be tested with 88 gravity (Baumé) gasoline. Correct designations of what we usually call 64° gasoline are—

| | |
|---|---|
| Gravity of gasoline (Baumé scale) | 64° |
| Specific gravity of gasoline | .7216 |
| Density of gasoline, pounds per gallon | 6.03 |

Designation of grade of gasoline by the weight per gallon is just as accurate as by either the Baumé scale or the specific gravity, and above all entirely definite and self-explanatory. There is some discussion of the advisability of purchasing the fuels by weight and not by measure. The adoption of the standard of weight for specifying them would be very desirable.

In conclusion, the purpose of this paper is four-fold:

First, to present a considerable amount of data in a way to make them useful to the average engineer.

Second, to advocate a horsepower formula based on unit displacement.

Third, to advocate two standard motor tests, one a routine test and the other a complete test.

Fourth, to advocate the specification of motor fuels by pounds per gallon instead of Gravity Baumé or Specific Gravity.

## DISCUSSION.

E. B. Wood.—Mr. President, and gentlemen, this paper has been very interesting to me, as I have been engaged in this sort of engine testing work for seven or eight years. On some things I do not agree with Mr. Cox. I do not see the use of measuring the heat in the cooling water and exhaust, because you cannot possibly in the ordinary engine separate those two successfully. A good deal of the heat you get in the cooling water really belongs to the exhaust, and is taken up from the water-cooled exhaust passages. After all what good is it? It is all waste heat, when you have separated them. The heat equivalent of the BHP is a good enough approximation for the radiator maker.

The testing of volumetric efficiency is very useful, because it gives a very effective check on the wonderful results you see published; results obtained by possibly inaccurate methods—in which it is claimed that mean effective pressures (on the BHP) of 130 pounds per square inch have been obtained.

This M.E.P. of 130 would represent an M.E.P. of quite 150 lbs. per square inch on the indicated HP. I am much inclined to doubt these figures, especially when obtained at very high speeds.

The friction losses would be exceptionally useful if you could measure them, but I have never come across any way of accurately measuring these, because if you simply motor the engine you eliminate a lot of things that cause friction when you are actually running under power. For instance, half the friction loss in the engine is due to the piston. I think Mr. Chase has done some experiments on that. When you motor

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the engine you entirely cut out the side-thrust of the piston against the cylinder wall due to the explosion. So I think it is unfair to assume an indicated-horsepower on those lines. Unfortunately the optical indicator cannot be relied on for accurate records. It gives you a very good indication of what the valve action is and also the shape of the peak shows how the ignition is behaving. All those I have seen required setting by hand, and that is somewhat unreliable owing to the lag in the piping connecting the cylinder with the diaphragm of the indicator. I am speaking, of course, of the high-speed type. I have tested an indicator on a small motorcycle engine running up over 4,000 revolutions.

T. J. FAY.—Since the loss of the radiator is the major portion, representing from 35 to 50 per cent. of the thermal value of the fuel, I do not understand why any engineer whose duty it may be to deliver results, should so far court failure as to ignore the required capacity of the radiator in a given case, or decline to ascertain the requirement of the motor in this regard, especially since it has long been known that no two designs of motor act alike in the heat balance, and, for that matter, some motors are over liberal in the proportion of heat that they so nonchalantly toss to the water in the jacket.

A. P. BRUSH.—Mr. President, without suggesting any criticism at all of the very excellent paper, it seems to me that there are one or two points that perhaps it would be well to amplify or supplement if we have the time, two points in particular. Mr. Cox has spoken of the relative difference between the long- and short-stroke engines. I presume he was referring to a specific form of cylinder and making his comparison entirely in that way.

C. E. COX.—No, different forms of cylinders were used in making the tests.

A. P. BRUSH.—Mr. Cox said nothing of the reason for the ratio of stroke to bore causing the effect, then. The reasons, I believe—at least I do not think of any others—are direct leakage around the piston, the friction losses due to difference in leverage in proportion to size of crankshaft and crankpin bearings, and heat losses of the radiator. We can readily see that direct leakage around the piston and the leverage of the crankshaft in reference to pin size will be independent of the type of the cylinder, but the difference in loss to the radiator will, I think, be governed rather more by type of cylinder than by ratio of bore to stroke. The heat losses to the radiator must necessarily be primarily from the combustion chamber, rather than the lower reaches of the stroke, where the cylinder wall is subjected to less heat. The Knight type, the overhead-valve motor, or any form of motor which gives a combustion chamber most nearly approximating a sphere, will necessarily give the least combustion-chamber wall-area subject to the extreme heat of combustion at maximum pressure. I think it probable that a comparison of this kind carried out between different types of engines would show materially more value in the long stroke with the L or T form of motors, by causing a greater reduction of combustion chamber wall area, than the overhead-valve motors. It does not seem to me that the difference between

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a stroke to bore ratio of one to one and one and a half to one could possibly make a difference in combustion chamber wall area, in the overhead type of motor, for example, that it would in the L or T.

With regard to the balancing of the six-cylinder motor, Mr. Cox treated entirely of vibration impulses affecting the entire mass of matter and did not go into what I believe of at least equal and, sometimes, of greater importance, the vibratory tendencies within the motor which might very possibly be destructive to bearings and parts. What Mr. Cox said about the parts balancing each other at any speed is, of course, obviously quite true. On the other hand, taking the effect of centrifugal force and acceleration and deceleration of reciprocating parts, it is quite apparent that with the crank in the position shown, the upward effect of the crankpin connecting the two central cylinders and the inertia of their reciprocating parts is concentrated in a line between these two cylinders, and is balanced by the aggregate of two pairs of reciprocating and rotating parts with their impulses, respectively, concentrated midway between cylinders 1—2 and 5—6, which obviously sets up stresses within the motor. On the other hand, when the crankpins for cylinders numbers 1 and 6 are passing their upper or lower dead center, they are balanced by forces acting between them and not concentrated at C, but distributed over a considerable distance, resulting in less acute stresses. You have all of you, of course, been familiar with some six-cylinder motors which at certain speeds show a critical period of vibration that is apparently entirely different from the total vibration of the whole mass of the motor. I cannot speak with any exact authority, but I have made some tests which lead me to believe that it is these internal stresses within the motor that are responsible for this, and I can say from my own experience that except for an increase in the total weight of the motor, and some increase in cost, there is a great benefit to the motor in treating the crankshaft as three separate units. In other words, if the two center cylinders and their cranks be treated as integral and the two pairs of end cylinders be treated as two others and counterbalanced by rotating balances, you can readily see that the internal stresses can be materially reduced. It is possible, of course, not only to entirely eliminate the internal stresses due to rotation of the crankshaft and lower ends of connecting-rods, but in some part those due to the reciprocating action of the pistons and upper ends of the connecting-rods. It would be well for us to give some consideration not only to what Mr. Cox has so succinctly outlined, but to those other problems of internal vibratory stresses with which I think we are all more or less familiar.

V. R. Heftler.—On the subject of balancing the crankshaft, it is interesting to compare the three-bearing and four-bearing ones. As far as the action of centrifugal force is concerned, I believe the three-bearing crankshaft superior. At each crankpin there is developed a certain centrifugal force, all of the same magnitude and in a radial direction. In the four-bearing crankshaft, the forces induced at the first two crankpins have a resultant bisecting the angle made by the two

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first arms, and therefore directly opposite the arm leading to crankpins 3 and 4, and, the angle being 120, the resultant force will be of the same magnitude as each of the components.

The forces induced at crankpins 5 and 6 will be compounded in the same manner, while the forces at 3 and 4, being parallel, will result in a force twice as great. By compounding these forces between the crankshaft bearing one sees that the four-bearing crankshaft is subjected in the center span to a certain force and at each end span to a force half as great, but in the opposite direction. In the three-bearing crankshaft these forces between adjacent support are in equilibrium, neglecting only a very small couple.

On the subject of vibration, three years ago while working on a small six-cylinder 80 mm. by 120 mm. we had the cylinders cast in blocks of two, using parts of our four-cylinder motor, and, as the intake was cored between cylinders, these were quite long. We had the thresh at about 1,200 r.p.m. We increased the crankshaft diameter and the critical speed rose to 1,400. Having decided to change the location of the magneto, we were enabled to put the carbureter on the valve side, thus doing away with the cored intake passage and shortening the cylinder. The critical speed rose to 1,800. We found afterwards that the critical speed varied in the same ratio as would indicate the formula giving the natural period of vibration of a beam, a formula in which enters the moment of inertia, the modulus of elasticity and the length.

C. E. Cox.—We ran the motor at a certain speed and then determined the time required to accelerate to a certain other speed with a full-open throttle; the tests were not conclusive and could not be used in making these tables.

C. H. Taylor.—With regard to what has been termed here, I think, the internal deflection of the crankshaft, that is, any vibration set up owing to internal deflection, it might be interesting to hear that about a year and a half ago I made some experiments on a two-bearing four-cylinder motor, which proved that at a speed of about 2,400 r.p.m., it had a stroke nearly ⅛ inch longer in the two center cylinders than in the two outside ones. It was not a badly designed motor either.

L. V. Cram.—I have been particularly interested in the average curve which Mr. Cox has shown, because I have been trying to make some comparisons along that very same line. It has seemed impossible to obtain a curve with any meaning for the reason that different valve sizes, timings, compression and spark advance play such important parts. From a considerable amount of data which we possess no one could fairly judge what a characteristic curve for any given conditions should be. I understand that some people forecast their curves but do not believe that any characteristic curve for a new line of motors can be accurately determined from all the data now available. It seems to me that in work of this kind it will be necessary to take all standard types of motors with different fits and displacements, but with the same relative valve areas, compressions and timings, and from the results of tests on these make characteristic curves for each type. It would also be necessary to intro-

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duce curves showing the effect of the variables on the characteristic results. In time sufficient information will be at hand and these curves will have an immense value.

C. E. Cox.—I agree with Mr. Brush that there are forces on the crankshaft due to the pistons and connecting-rods which must be taken care of by the strength of the crankshaft, and a four-bearing crankshaft must be rigid enough to balance itself; that is, to prevent deflection due to the centrifugal forces acting at different points along the shaft. In the seven-bearing crankshaft, this is not the case; it is self-contained. Each piston and connecting-rod have the benefit of two bearings, so that the shaft has to transmit only the torque. A three-bearing six-cylinder shaft must be still stronger than a four-bearing. It was assumed in this discussion that the four-bearing crankshaft must be made heavy enough to transmit the torque and take the pressure of explosion without deflecting sufficiently to produce vibration, and it was then assumed that the shaft was heavy enough to take care of any forces introduced by the balancing weights necessary on the shaft at different points.

Regarding Mr. Cram's suggestion of testing different classes of motors, I would say that this is very desirable, but the data available for this paper were not sufficiently comprehensive to enable me to plot curves showing the different types of motors. These curves were plotted in order to compare them with the A.L.A.M. formula and other methods of computing horsepower. When more data are available from tests of different sizes of motors, showing spark and throttle positions, additional curves can be plotted.

A. P. Brush.—I judge from what Mr. Cox has just said that I did not make myself entirely clear. I spoke of the centrifugal force of the crankpins and part of the connecting-rods. But I also meant to call attention to the fact that the reciprocating parts supplement this in vertical plane; and I have to disagree with Mr. Cox for the first time, in regard to his statement that it is possible, in any practically proportioned engine, to depend upon the stiffness of the crankshaft to overcome those stresses. The bearings themselves must take up the major part of them.

If any of you care to make a very simple experiment, take any four-cylinder crankshaft of the stiffest design which you can get and rotate it freely between centers, at high speed, and you will see very quickly that the centrifugal force is sufficient to make a very perceptible spring in it. As you add to the stiffness you necessarily add to the weight and to the centrifugal force, but not as rapidly as you do to the stiffness, to be sure; however, the gain in stiffness over centrifugal force is much too slow to make it possible to depend on the stiffness of the crankshaft to keep these strains off the bearings. In a six-cylinder, of the four-bearing type shown, the bearings, and through them the motor structure, must absorb these forces. I am merely calling attention to the possibility of neutralizing a large part of these forces so as to reduce the effect of them upon the bearings and to bring them down to so small an amount that in an ordinary motor structure they would not produce perceptible periodic synchronized vibration. I have seen very few, if any, six-cylinder

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motors, especially of the four-bearing type, that would not show at some one speed a synchronism between those tendencies which I spoke of and the natural vibration of the motor structure. I have been able to reduce that to an imperceptible amount by the modifications outlined.

E. R. FRIED.—I agree with Mr. Brush entirely on the point that stiffness of the crankshaft does not increase as rapidly as the centrifugal force due to the increased weight of the crankpin. A good example of the vibration of balanced parts is in steam turbine work, where a perfectly balanced wheel will cause a vibration sufficient sometimes to break the shaft at a certain speed, due to the synchronism between the natural vibration of the motor and the vibration of the revolving part at that speed.

There is only one possible way of balancing absolutely a six-cylinder motor, and that is to balance each revolving and each reciprocating part in its own plane. Now it is not possible to balance reciprocating parts with revolving parts on account of the finite length of connecting-rod, but it is possible to balance the crankpins and arms by counterweights. The centrifugal forces set up by the cylindrical part of the crankshaft marked No. 4 on the illustration, are, I believe, so great within the range of moderate motor speed as to set up a vibration noticeable in the motor. Different types of connections between No. 1 and No. 2 and No. 5 and No. 6 crankpins are possible, as Mr. Cox says, which we are able to balance by adding weight on the crankpin. A little difference between the weight is necessary on No. 4, with the connecting arm going straight through and inward. But that difference is hardly worth speaking about.

A six-cylinder motor has very little vibration due to the unbalanced part of the pistons, on account of crank arrangement. But still, being the only unbalanced force of the reciprocating part, it has to be reduced as much as possible. One part of the connecting-rod follows a revolving, another a reciprocating motion. Assume that the two parts are not similarly divided in the different cylinders, I mean the reciprocating part of the connecting-rod in different cylinders is different; we have a vibration which is not a vibration of sixth period, as the reciprocating parts are in a six-cylinder motor, but is of the first period. I believe that balancing the pistons between each other within very close limits and balancing the connecting-rods, not as a whole but both ends, the one which is reciprocating and the one which is revolving, would help a whole lot. This will not eliminate the critical vibration which is only natural in every motor, but will increase the speed at which this critical vibration will occur.

C. E. Cox.—I would like to say a few words in regard to Mr. Brush's last comments. If we use a four-bearing crankshaft there are some forces which must be taken care of in the strength of the shaft. If counterweights are put in between the end bearings and the second bearings, weight is added to the shaft, increasing the forces to be taken care of by the shaft between those two bearings. The force is still there to be taken care of. It would be a nice point to determine whether, in adding counterweights to help balance, the reciprocating parts would not increase

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the deflection of the shaft rather than lessen it. A great deal of mathematical research has failed to show just where the weight would do the least harm. I still adhere to the idea that if the shaft is as heavy as it should be in order to take the force of the explosion without deflection, it will take care of the necessary weight required to balance the shaft within itself, providing the lightest and most rigid design is used.

# Notes on Power Variation with Atmospheric Changes

By Herbert Chase

(Member of the Society)

The purpose of this brief paper is to place in your hands a limited amount of data with respect to variations in the power of a motor due to atmospheric changes, with a view to provoking further discussion of the subject and inducing others to submit definite data which will settle what is now a mooted question. The writer frequently hears the assertion that automobile motors run better at night than in the daytime, and develop considerably more power. It is said that hills which a car will not take on high gear during the day can be climbed without difficulty on top speed at night. Just how much of this is mere fancy which can be laid to some psychological phenomenon affecting the driver of the car, and how much has some basis in fact, is a question which has never been satisfactorily answered so far as I am aware.

During the past month there was conducted in the laboratory of the Automobile Club of America under my general oversight a test of a Packard motor. This motor ran continuously with the throttle wide open for a period of 300 hours. The speed was maintained as nearly constant as possible by making slight variations in the load. During most of the time the doors and windows of the laboratory were wide open, so that there was no marked difference between the atmospheric conditions inside the room and out-of-doors. If then the night air is productive of beneficial effects upon the power which a motor develops, there was every opportunity for the difference to show itself. I have, therefore, averaged the power developed over a period of four days and find a difference of less than 1 per cent. as between the average power from 6 a. m. to 6 p. m., and from 6 p. m. to 6 a. m. on these days, the slight difference being in favor of the day rather than the night periods. The difference, in fact, is very much less than that occurring between many successive fifteen-minute intervals.

Just why a motor should develop more power at night, if it be true that it does so in some cases, is a question which I am unable to answer to my satisfaction. The ordinary changes in temperature and in the quantity of water vapor present in the air may have some slight effect,

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but it hardly seems probable that they resulted in change of power sufficient to be detected save by the most sensitive dynamometer.

Marked changes in barometric pressure do have an appreciable effect upon the power output of a motor, however, and this fact can be demonstrated readily by a very simple experiment. The data given below show clearly what change resulted from definite variations of this character.

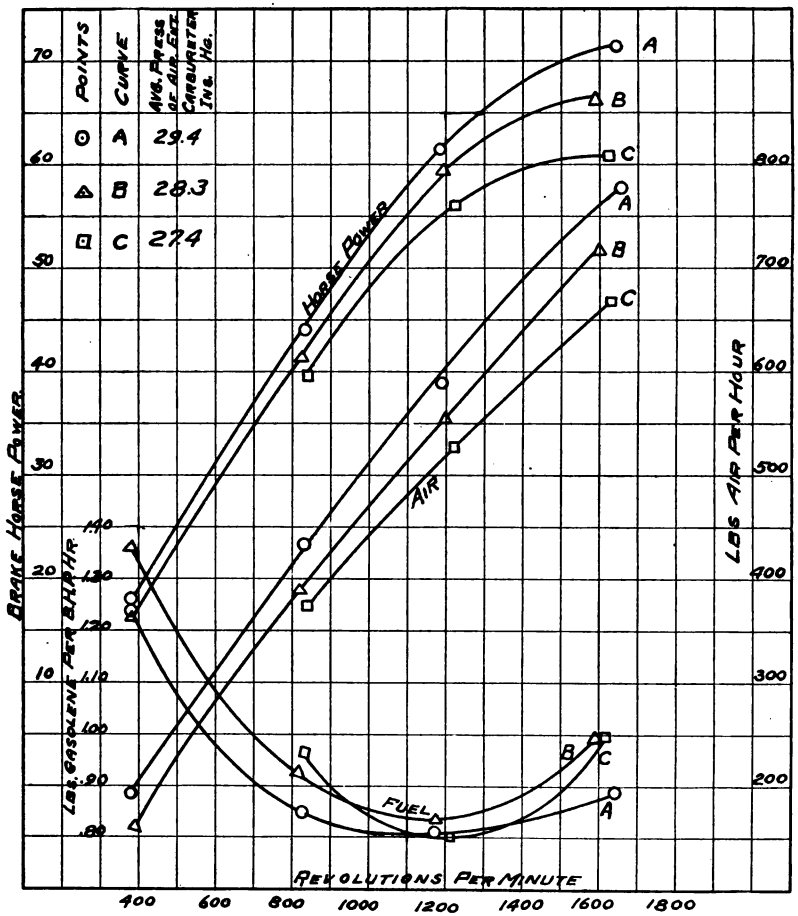


Chart No. 1

The experiment was performed as follows:

The carbureter used on the motor to be tested was enclosed in a box which had but one opening to the atmosphere. To this opening was

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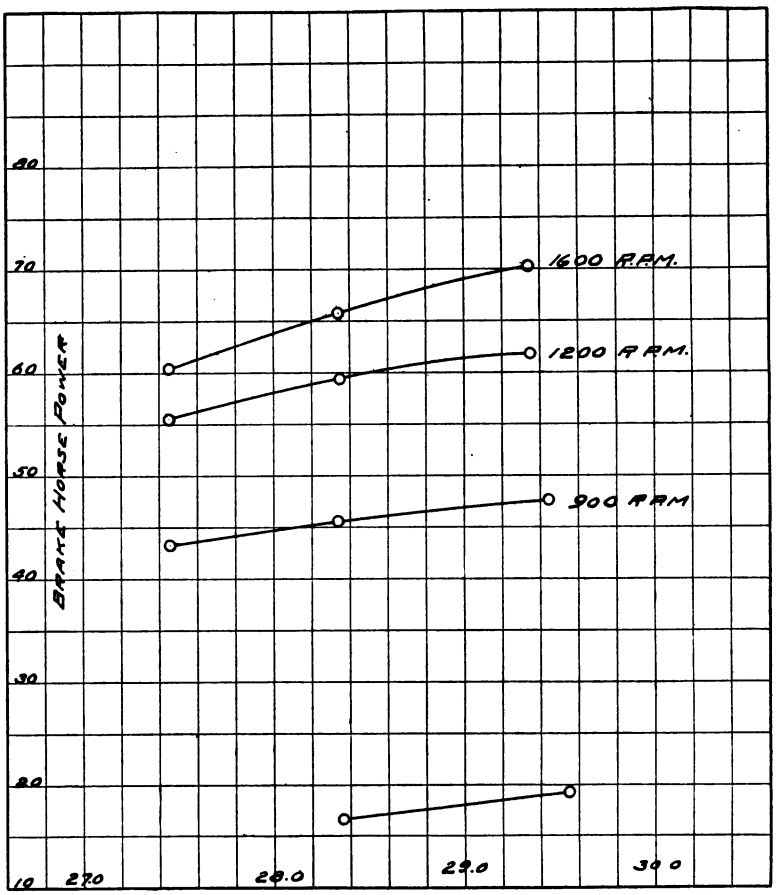


Chart No. 2

connected an expansion chamber and a venturi air-meter with a 2-inch throat. Attached to the inlet of this meter was a 2-foot length of 3-inch pipe. Near the outer end of the latter an ordinary butterfly throttle (designated "Throttle A" below) was inserted. A mercury manometer was connected to the box containing the carbureter in such manner as to measure the drop in pressure of the air entering the carbureter.

The throttle above the carbureter was fastened wide-open during all the tests, and the spark was adjusted for maximum power in each run.

Three runs were then made at each of four different speeds, namely, 400, 800, 1,200, and 1,600 r.p.m. (approximately). The first run at each speed was made with throttle "A" wide open, and note was made of the

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drop in pressure at the carbureter, due to friction in the air line. For the next run throttle "A" was partly closed until the pressure of the air entering the carbureter was reduced by about 1 inch of mercury below the previous reading. A third reading with throttle "A" closed to give a drop of approximately 2 inches of mercury was then made. In each instance the load on the motor was reduced sufficiently to maintain the same speed as for wide throttle. The temperature of the water entering the motor was held substantially constant, as were also the temperature and humidity of the entering air.

The effect of partly closing throttle "A" is to give practically the same conditions as a decrease in the barometer reading. The results of this decrease in pressure on the power of and consumption of air and fuel by the motor is best appreciated by reference to chart No. 1. The loss of power at 1,600 r.p.m., due to a drop of 1 inch of mercury, was approximately 5 horsepower in 71 or 7 per cent., while a 2-inch drop doubled the loss. At 1,000 r.p.m. the losses were about 3.5 and 6.0 horsepower, respectively, in 31 horsepower, or about 11 and 19 per cent.

The curves in chart No. 2 show the relation between barometric pressure and brake horsepower.

All the data taken have not been plotted but are given in the accompanying table.

| Run | Duration of Run, Min. | Revolutions per Min. | Torque, Lbs.-Ft. | Brake-H.P. | Gasoline, Lbs. per B.H.P.-Hr. | Gasoline, Lbs. per Hour | Ratio Air to Gas by Wght. | Air per Hour, Lbs. | Free Air per Min., Cu. Ft. | Temperature F.° Air Entering Carbureter | Temperature F.° Cylinder Jacket Water. In | Temperature F.° Cylinder Jacket Water. Out | Pressure Below Atmosphere Ins. Hg. Below Carb. | Pressure Below Atmosphere Ins. Hg. Above Carb. | Exhst. Back Pres., Ins. Hg. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A | 3 | 1641 | 224 | 70.1 | 0.88 | 61.7 | 12.2 | 750 | 164. | 55 | 128 | 156 | 0.2 | 1.8 | 11.7 |
| B | 3 | 1595 | 219 | 66.5 | 0.98 | 64.5 | 10.9 | 704 | 154. | 54 | 126 | 154 | 1.2 | 2.4 | 10.9 |
| C | 3 | 1614 | 197 | 60.5 | 0.99 | 60.0 | 11.2 | 670 | 147. | 54 | 125 | 153 | 2.1 | 3.4 | 9.6 |
| D | 3 | 1183 | 270 | 60.9 | 0.80 | 48.7 | 12.1 | 591 | 129.5 | 55 | 127 | 158 | 0.2 | 1.2 | 7.1 |
| E | 3 | 1187 | 262 | 59.1 | 0.82 | 48.5 | 11.3 | 550 | 120.5 | 55 | 126 | 158 | 1.2 | 2.2 | 6.6 |
| F | 3 | 1205 | 247 | 56.8 | 0.79 | 44.8 | 11.7 | 525 | 115. | 55 | 127 | 159 | 2.1 | 3.0 | 6.3 |
| G | 3 | 814 | 284 | 44.0 | 0.84 | 37.0 | 11.8 | 436 | 95. | 54 | 126 | 161 | 0.1 | 0.8 | 3.5 |
| H | 3 | 802 | 269 | 41.1 | 0.92 | 37.8 | 10.2 | 384 | 84.1 | 54 | 124 | 168 | 1.2 | 1.8 | 2.4 |
| I | 3 | 822 | 255 | 39.9 | 0.95 | 37.9 | 9.8 | 370 | 81.1 | 54 | 125 | 157 | 2.1 | 2.8 | 2.4 |
| J | 3 | 375 | 248 | 17.7 | 1.17 | 20.7 | 9.3 | 192 | 42. | 54 | 122 | 170 | 0.0 | 0.6 | 1.3 |
| K | 2 | 375 | 224 | 16.0 | 1.29 | 20.7 | 7.8 | 161 | 35.2 | 54 | 123 | 174 | 1.2 | 1.6 | 1.2 |

BAROMETER READING 29.53" Hg.

## DISCUSSION

HERBERT CHASE.—If you will refer to the curves, I will tell you exactly what they represent. The curves marked *A* were taken with the throttle outside the carbureter wide-open, so that the conditions in the box which enclosed the carbureter were practically the same as in the room.

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The barometric pressure at that time was 29.4 inches. The curves marked *B*, Chart No. 1, were taken with an average drop of 1.1 inches or when the pressure within the box corresponded to 28.3" of mercury barometric pressure. The curves marked *C* corresponded to 27.4" barometric pressure. The three upper curves show the brake-horsepower as plotted against speed. The next lower set of three curves shows the flow of air in pounds per hour and the three curves near the bottom of the sheet the fuel consumption in pounds per brake-horsepower-hour.

PRESIDENT MARMON.—You have all heard people claim that their cars run better at night than in the daytime. This paper does not seem to indicate that they do.

C. P. GRIMES.—I would like to ask Mr. Chase just how large the box in which he enclosed the carbureter was and what arrangement he had for preventing the pulsations that ordinarily occur in and around a carbureter under those conditions.

HERBERT CHASE.—The volume within the box was approximately one cubic foot. This box was connected to a large expansion chamber, the capacity of which was about four or five cubic feet, and to this in turn was connected the venturi tube. With this arrangement I believe the pulsations were so nearly damped out as not to affect appreciably the records here given. Furthermore, this test was made with a six-cylinder motor, in which the pulsations are much less pronounced than in the four-cylinder type.

F. JEHLE.—The information Mr. Chase has gathered is very interesting. It has always been a question in my mind whether atmospheric conditions really affect motor performance as much as some of us thought they did. Nearly all of us have recorded barometer, humidity and temperature readings of the air, but I do not know of one who has ever used the results in any calculation. For this reason I started a discussion some time ago in the Detroit Section of the Society.* I calculated some of the losses that we might expect. Of course, I found practically no change, possibly about one per cent. or less, due to decrease in density of air caused by a one inch drop of the barometer. That was only for the motor. I could not calculate how the carbureter would behave, and I came to the conclusion that practically the whole loss was due to the carbureter, or that there was not as much loss as we thought there was. Mr. Chase's paper, however, I think proves that there is a loss, and that loss seems to be very great, as high as ten per cent. for an inch. I am sorry that Mr. Chase could not go a little further and reproduce different conditions in the air as regards humidity. I do not think, however, that the tests show that a small change in barometer, such as we ordinarily encounter during day and night, would affect the performance of the motor.

The gasoline curves are rather interesting. The lowest consumption we have at the highest barometric pressure, and fairly parallel to the high pressure fuel curve, is the one for a decrease in pressure of one inch.

*See page 328.

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The lowest pressure fuel curve does not seem to adhere to any particular law. It shows a higher consumption at the beginning and the best consumption around 1,200 revolutions. I would like to ask Mr. Chase whether he tried to obtain any higher pressure than atmospheric.

HERBERT CHASE.—I did not. I would have liked to investigate the effects of high pressures as well as those due to changes of humidity, but time did not permit.

F. JEHLE.—Without making any calculations at all the change in pressure did not seem to affect the volumetric efficiency. If I understand the curves correctly, you have reduced the cubic feet of air to atmospheric conditions. The different curves represent air at normal pressure, not the pressure that was in the box.

HERBERT CHASE.—The curves show the pounds of air consumed per hour. The meter reads in cubic feet per minute at standard conditions; hence a correction has been applied to the figures given, to allow for the decreased density of the air in the box.

If by volumetric efficiency you mean the ratio of the weight of air actually taken into the motor to the weight that would be taken in if the cylinders were filled full *at the temperature and pressure existing outside the carbureter* (which I take to be the correct definition of volumetric efficiency), I think you will find that the volumetric efficiency did not vary greatly at the different pressures, although I have not made the computations which would be necessary in order to answer your question with certainty.

C. P. GRIMES.—Mr. Jehle, in addressing the Detroit Section stated that the changes in the barometer had no noticeable effect on the action or horsepower of an automobile motor. I seriously objected to Mr. Jenle's remarks and in support of my objection beg to submit the results of a series of experiments I made during the flood period in Indianapolis last March.

Following are the data taken for Barometer study. Buick motor, valve-in-the-head, 3¼" x 3¼", 4-cylinder, water-cooled. Special valveless carbureter, no moving parts, 1" size. Standard manifold was used. The suction readings were taken from about four inches above the carbureter flange. The carbureter remained at same adjustment throughout.

| R.P.M. | Lbs. at 36" R. | H.P. | Pressure in Inlet Pipe Below Atmos. "Hg. | COOLING WATER | | |
|---|---|---|---|---|---|---|
| | | | | Inlet °F. | Outlet °F. | |
| 400 | 29.9 | 6.83 | .22 | 86 | 125 | March 14, '13. |
| 600 | 32.4 | 11.09 | .46 | 86 | 110 | 3:00 P.M. |
| 800 | 32.4 | 14.08 | .94 | 84 | 104 | Barom. 28.66" Hg. |
| 1000 | 33.00 | 18.85 | ..... | 84 | 100 | Room 75.0° F. |
| 1200 | 30.65 | 21.05 | 1.52 | 82 | 97 | |
| 1400 | 26.65 | 21.33 | 1.84 | 80 | 90 | |
| 1600 | 23.0 | 21.0 | 1.02 | 75 | 90 | |

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| R.P.M. | Lbs. at 36″ R. | H.P. | Pressure in Inlet Pipe Below Atmos. ″Hg. | COOLING WATER Inlet °F | COOLING WATER Outlet °F | |
|---|---|---|---|---|---|---|
| 400 | 32.2 | 7.35 | .20 | 116 | 150 | |
| 600 | 34.7 | 11.88 | .36 | 116 | 141 | March 17, '13. |
| 800 | 35.45 | 16.2 | .66 | 114 | 132 | 8:30 A.M. |
| 1000 | 36.4 | 20.8 | 1.12 | 114 | 130 | Barom. 30.00″ Hg. |
| 1200 | 35.2 | 24.15 | 1.34 | 112 | 127 | Room 60° F. |
| 1400 | 32.2 | 25.81 | 1.62 | 110 | 124 | |
| 1600 | 28.65 | 26.2 | 1.90 | 110 | 120 | |
| 400 | 26.7 | 6.1 | .03 | 120 | 142 | |
| 600 | 31.8 | 10.89 | .46 | 119 | 141 | March 20, '13. |
| 800 | 33.1 | 15.12 | .80 | 118 | 134 | 8:30 A.M. |
| 1000 | 34.0 | 19.4 | 1.16 | 116 | 130 | Barom. 29.12″ Hg. |
| 1200 | 32.8 | 22.5 | 1.50 | 114 | 127 | Room 70° F. |
| 1400 | 30.0 | 24.0 | 1.76 | 114 | 124 | Bright sunshine. |
| 1600 | 26.7 | 24.4 | 2.16 | 112 | 121 | |
| 400 | 31.5 | 7.2 | .20 | 82 | 115 | |
| 600 | 34.4 | 11.78 | .40 | 82 | 106 | March 21, '13. |
| 800 | 34.55 | 15.78 | .70 | 82 | 100 | 9:00 A.M. |
| 1000 | 35.3 | 20.08 | 1.10 | 80 | 96 | Barom. 29.09″ Hg. |
| 1200 | 34.0 | 23.3 | 1.40 | 80 | 93 | Room 60° F. |
| 1400 | 30.25 | 24.13 | 1.50 | 80 | 90 | |
| 1600 | 26.8 | 24.5 | 1.90 | 80 | 90 | |
| 400 | 30.9 | 7.06 | .14 | 100 | 125 | |
| 600 | 34.9 | 11.95 | .40 | 100 | 120 | March 21, '13. |
| 800 | 35.3 | 16.13 | .70 | 100 | 117 | 4:00 P.M. |
| 1000 | 35.6 | 20.35 | 1.10 | 98 | 114 | Barom. 29.50″ Hg. |
| 1200 | 34.55 | 23.68 | 1.32 | 98 | 110 | Room 60° F. |
| 1400 | 31.5 | 25.20 | 1.70 | 98 | 108 | |
| 1600 | 28.1 | 25.66 | 2.00 | 96 | 105 | |
| 400 | 33.45 | 7.64 | .16 | 90 | 114 | |
| 600 | 35.95 | 12.31 | .36 | 90 | 114 | March 22, '13. |
| 800 | 36.2 | 16.53 | .70 | 90 | 108 | 8:00 A.M. |
| 1000 | 37.0 | 21.13 | 1.06 | 87 | 104 | Barom. 30.06″ Hg. |
| 1200 | 34.75 | 23.80 | 1.40 | 87 | 102 | Room 52.0° F. |
| 1400 | 31.9 | 25.50 | 1.70 | 86 | 98 | |
| 1600 | 28.2 | 25.75 | 1.96 | 85 | 96 | |
| 400 | 30.5 | 6.97 | .14 | 110 | 138 | |
| 600 | 34.55 | 11.82 | .36 | 110 | 137 | |
| 800 | 35.2 | 16.1 | .60 | 110 | 130 | April 8, '13. |
| 1000 | 35.85 | 20.45 | 1.00 | 110 | 128 | 2:00 P.M. |
| 1200 | 35.5 | 24.3 | 1.40 | 110 | 124 | Barom. 29.56″ Hg. |
| 1400 | 32.5 | 26.0 | 1.96 | 109 | 120 | Room 58° F. |
| 1600 | 29.35 | 26.8 | 2.32 | 108 | 118 | Cloudy, wind low. |
| 1800 | 25.6 | 26.3 | 2.60 | 104 | 114 | |

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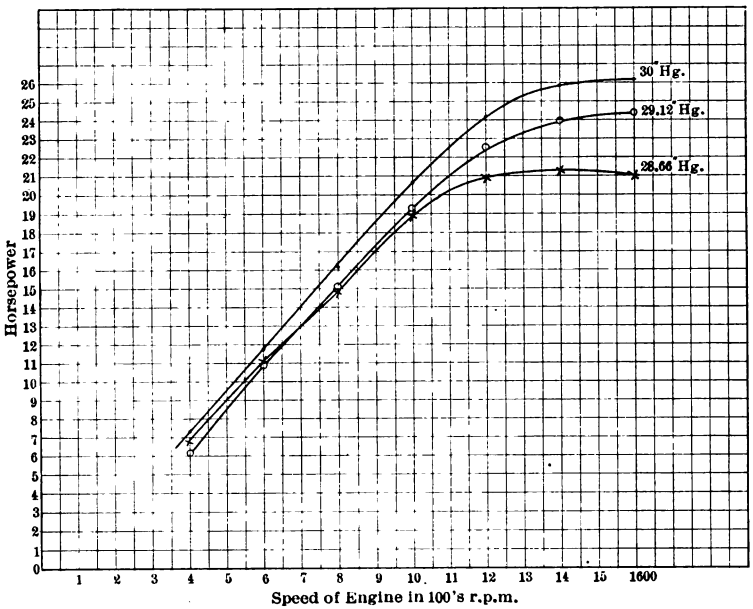


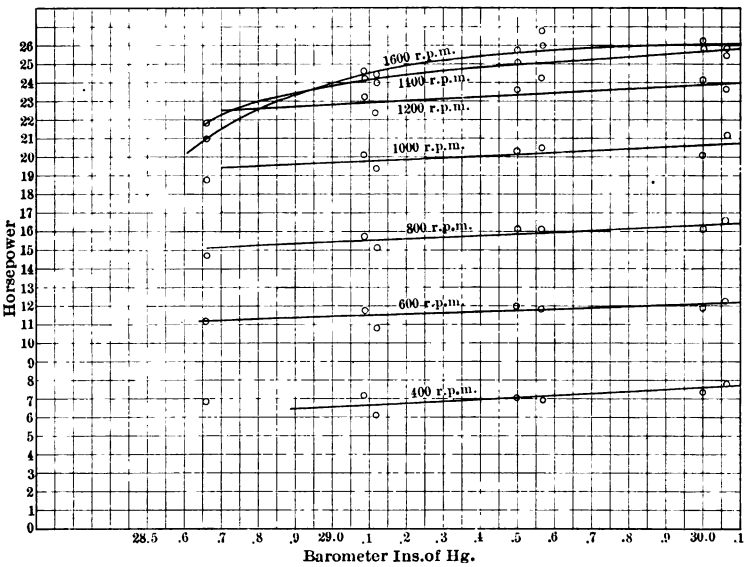


You will note that the curves have a very definite trend, showing in each and every case a decided increase in horsepower with an increase in the barometer reading.

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| *N* | *A* | *B* | *C* | |
|---|---|---|---|---|
| 400 | 6.6 | .95 | 14.4 | *N*, speed in r.p.m. |
| 600 | 11.35 | .80 | 7.05 | *A*, h.p. at 29.00″ Hg. |
| 800 | 15.4 | 1.00 | 6.49 | *B*, difference in h.p. between the |
| 1000 | 19.7 | 1.00 | 5.08 | readings taken at 29.0″ Hg. and |
| 1200 | 22.9 | 1.20 | 5.24 | 30.0″ Hg. |
| 1400 | 23.85 | 2.25 | 9.43 | *C*, percentage difference based on the |
| 1600 | 23.80 | 2.30 | 9.66 | lower or 29.0″ Hg. reading. Variation in h.p. with change of one inch in the barometer. |

I regret that lack of time has prevented me from giving these data more attention. I believe that a proper formula would give close readings of horsepower at different barometric pressures.

E. B. Wood.—I would like to call Mr. Chase's attention to a piece of apparatus that was used by Dr. Watson, of London, in some of his experiments on the flow of air through an orifice. You might almost call it a fluctuation meter. I think it was constituted of a little rubber diaphragm, with a metal contact in the center, with two micrometer screws for adjusting to make electrical contact with the diaphragm and so give the motion and fluctuations of the diaphragm. Dr. Watson found it necessary to use an air expansion chamber of at least nineteen cubic feet in order to get rid of these fluctuations. In fact, when we were at the Automobile Club of America, where they were running a six-cylinder motor for demonstration purposes, in spite of its being throttled down, one could feel the fluctuations by putting a finger in front of the air inlet.

I do not like the venturi tube method of measuring air. You might as well apply direct current methods to an alternating current problem as to try to calibrate an air meter of this description by the use of steady air currents and then use it for measuring the pulsating flow in an engine induction pipe. I fancy that Dr. Watson has done a series of experiments on that subject alone, but evidently with a very big expansion chamber.

C. H. Taylor.—Apparently increase in humidity does not affect the power of ordinary mixtures, that is to say, with a given mixture; but as the mixture is made weaker and weaker down to a point where it will not fire at all with dry air, you will get an increasing amount of power with increased humidity. At least that was the result of some experiments I tried some time ago. That was with a steam jet injection into the carbureter intake. I did not measure the quantity of humidity.

F. Jehle.—Mr. Taylor's experiment does not seem to agree with the experiments recently conducted at the Bureau of Mines and published in Bulletin 43. They ran several tests of injecting water with the charge and found out that by so doing compression could be increased (I think the highest was 140 pounds to the square inch for gasoline) without preignition. A slight increase of power was noted. If, however, water was injected with the charge at ordinary compression no increase of power was shown. They detected no increase in fuel economy either with increased or with normal compression.

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HERBERT CHASE.—The popular impression of increase in power, such at least as can apparently be noted on the road, may be due to an inclination to confuse power with ability to accelerate. Possibly certain changes in the mixture occur which cause the car to accelerate somewhat more rapidly, thus giving the impression that the car actually has more power, whereas the difference is really one of carburetion—when the motor once attains a certain speed the power is substantially the same, but in one case the speed is reached more quickly than in the other because the mixture for accelerating was better.

With respect to the fluctuation of flow in the venturi as a means of measuring air flow, I have this to say: when Mr. Wood was at the club's laboratory he noted the fluctuating flow of the air entering the venturi. At that time there was no large expansion chamber in the line. The experiments noted in my paper were made with an expansion chamber. But I venture to say that even without one the fluctuation in the venturi reading with this motor the error would not be more than one or two per cent. In certain cases where the valve-timing varies considerably and where the fluctuation in pressure is considerable, a difference in size of the expansion chamber will make a great difference; there can be no question about it. With most motors I have been unable to notice any great difference with a moderate-sized expansion chamber. With some motors it is impossible to run at all when drawing the air through a fairly long pipe line without having a considerable expansion chamber in the line.

# A CONSIDERATION OF CERTAIN PROBLEMS OF CARBURETION

By ARTHUR B. BROWNE

(Member of the Society)

The lack of uniformity exhibited by the great and ever-increasing variety of carbureters on the market, suggests that as yet, no comprehensive principle of automatic regulation of the gas to air ratio has been generally recognized. The simplest form of carbureting device consists of a fuel jet introduced into the moving air column within the intake pipe. If the velocity of the fuel flow were directly proportional to the velocity of the air flow, the mixture from such a device would be of constant composition under all conditions and the principal problem of carburetion would be resolved at once to its simplest terms. Unfortunately the relation between the air and fuel velocities is not a direct proportion, but, as will be demonstrated, it is none the less definite. Once recognized, its application to practical carburetion not only eliminates the necessity for most of the mechanical complications now in use but it explains clearly the errors which are introduced by their use.

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## THE LAW OF GRAVITY APPLIED TO CARBURETION

The law of the flow of fluids, including gases within certain limits of pressure differences, is expressed

$$v = \sqrt{2gh} \tag{1}$$

where

$v$ = velocity in feet per second.
$g$ = acceleration of gravity (32.2 feet per second).
$h$ = head, or height in feet of the fluid, required to produce the pressure necessary to cause the flow.

The velocity of the air ($Va$) in a carbureter will be expressed

$$Va = \sqrt{2gh} \tag{2}$$

whence

$$Va^2 = 2gh \tag{3}$$

and

$$h = \frac{Va^2}{2g} \tag{4}$$

In this case, $h$ is the height in feet, of a column of air, the weight of which will exert the pressure necessary to cause a flow of air at the velocity $Va$, or conversely, the loss of head caused by the air flowing at the velocity $Va$.

The head of fuel caused by air passing at a velocity $Va$, will be

$$h \times \frac{Wa}{Wf}$$

where

$Wa$ = weight 1 cubic foot of air (.076 pounds at 62° F.).
$Wf$ = weight 1 cubic foot of fuel (weight 1 cubic foot of water [62.355 pounds] × Sp. Gr. of fuel).

Applying equation (2) to the fuel velocity, $Vf$, we have

$$Vf = \sqrt{2gh \frac{Wa}{Wf}}$$

But as, before actual discharge commences, the fuel must rise from the level in the float chamber to the mouth of the fuel nozzle, a distance of $h'$ feet, subject to the retardation of gravity, we must deduct the value of $2gh'$ and hence

$$Vf = \sqrt{2gh \frac{Wa}{Wf} - 2gh'}$$

Substituting the value of $2gh$ as determined by equation (3), the velocity of the fuel is expressed in terms of air velocity as follows:

$$Vf = \sqrt{\frac{Wa}{Wf} Va^2 - 2gh'} \tag{5}$$

Wimperis (The Internal Combustion Engine, page 268), arrives at the same relation between air and fuel velocities by methods of the calculus.

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### EFFECT OF TEMPERATURE

The density of both fuel and air is, of course, modified by temperature. The density of the air varies inversely as the absolute temperature, while the density of gasoline is shown by Clerk and Burls (The Gas, Petrol and Oil Engine, Vol. II, page 623) to be modified by temperature as follows:

$$\text{Sp. Gr.} = 0.72 \left\{ 1 - .0007 \, (t - 60) \right\}$$

whence

$$Wf = W \times s \left\{ 1 - .0007 \, (t - 60) \right\} \tag{6}$$

where

$Wf$ = weight of 1 cu. ft. of gasoline.
$W$ = weight of 1 cu. ft. of water.
$s$ = specific gravity of gasoline at 60° F.
$t$ = temperature of the gasoline in F.°.
$t'$ = temperature of the air in F.°.

Substituting these values in equation (5) we have:

$$Vf = \sqrt{\frac{\frac{(460 + 62)\ 0.076}{460 + t'}}{62.355 \times s \left\{ 1 - .0007 \, (t - 60) \right\}} (Va^2 - 2gh')} \tag{7}$$

The range of values for $t$ and $t'$ to be used in equation (7) is so small that it will be readily seen that the effect of temperature is negligible.

### WORKING FORMULÆ

Omitting the temperature correction, a simple working equation for gasoline of a Sp. Gr. of 0.72, may be expressed

$$Vf = \sqrt{(.00169\, Va^2) - 2gh'} \tag{8}$$

For fuel of any other gravity, equation (5) becomes

$$Vf = \sqrt{\left(\frac{.076}{62.355\, s} Va^2\right) - 2gh'}$$

which reduces to

$$Vf = \sqrt{\left(\frac{.00122}{s} Va^2\right) - 2gh'} \tag{9}$$

### APPLICATION OF THE LAW TO VARIOUS TYPES

In order to obtain a clear understanding of the application of the law, let us consider the action of various types of carbureting devices in view of the relation of air and fuel velocities as expressed in equation (8).

Assume (A) that a unit quantity of air is passing each device with a given velocity and then (B) that a greater quantity of air is demanded. For the sake of uniformity let us assume that each device maintains a constant level of fuel 0.5 inch (0.0416 feet) below the mouth of the fuel nozzle and that the fuel employed is gasoline of a specific gravity of 0.72.

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## I. THE SIMPLE CARBURETER

(A) In this device, the velocity of the fuel discharge for an air velocity of say 90 feet per second will be, by equation (8)

$$Vf = \sqrt{(.00169 \times 90^2) - (64.4 \times .0416 \times 0.72)} = 3.43 \text{ ft. per sec.}$$

(B) As the area of air admission is constant, four times the air will pass at four times the velocity. By equation (8) this will induce a fuel flow of

$$Vf = \sqrt{(.00169 \times 360^2) - 1.9} = 14.73 \text{ ft. per sec.}$$

Hence, while the quantity of air has been increased four times, the quantity of fuel has increased 4.4 times and the resulting mixture is 10.4 per cent. richer than formerly.

## II. THE MIXING VALVE

In this device, head, pressure on the valve, amount of valve opening, admission area exposed by said opening and the quantity of air admitted are in direct proportion to each other, if friction is disregarded. It follows therefore, that, as the head varies with the square of the velocity (Equation 4), the quantity of air bears the same relationship. Conversely we may state that the velocity varies as the square root of the quantity of air admitted.

(A) The fuel flow, for an air velocity of 90 feet per second will be 3.43 feet per second as in (I-a).

(B) By the proportion stated above, four times the initial quantity of air will pass the apparatus at twice the initial velocity. Hence the fuel flow induced by the increased quantity will be, by equation (8)

$$Vf = \sqrt{(.00169 \times 180^2) - 1.9} = 7.27 \text{ ft. per sec.}$$

showing that while the air quantity has increased four times, the fuel quantity has increased only 2.17 times, or but 54 per cent. of the fuel is present that is necessary for a constant mixture. It is thus readily seen why the mixing valve cannot be used for carburetion where any material degree of flexibility is desired.

## III. THE COMPENSATING CARBURETER

Attempts to correct the tendency to over-richness exhibited by the simple carbureter, led to the early adoption of the auxiliary air-valve. The popular conception of the auxiliary-air inlet is that the air thus admitted serves to dilute the necessarily over-rich mixture formed at the mouth of the fuel nozzle. As all the air entering the carbureter, through either the primary or auxiliary inlet, finally reaches the cylinders as part of the explosive mixture, the foregoing statement is obviously true, but the most important function of the auxiliary inlet is likely to be lost sight of in such an explanation of its purpose.

The area of the auxiliary opening modifies the velocity of all the incoming air and hence exercises a direct influence upon the amount of fuel inspirated. This function will be better understood if the primary and auxiliary inlets are considered as a divided unit. Any enlargement of

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the auxiliary area increases the *total* area of admission and hence modifies both quantity and velocity.

In a carbureter of this type let

$Q$ = the quantity of air.
$V$ = velocity of the air.
$a$ = auxiliary area.
$c$ = the primary area.
$A$ = total admission area $= a + c$.
$g$ = acceleration of gravity.

Disregarding friction, the quantity of fluid discharged by an orifice is expressed

$$Q = VA \tag{10}$$

Hence the quantity of air passing the carbureter will be

$$Q = V(a + c)$$

which, by substituting the value of $V$ from equation (1) may be written

$$Q = (a + c)\sqrt{2gh} \tag{11}$$

In this equation $h$ is the height of a column of air necessary to cause a unit deflection of the spring governing the auxiliary valve; therefore the velocity of a given quantity of air is directly dependent upon spring tension and deflection, as well as upon the relative areas of both primary and auxiliary openings. As these variables are fixed by construction, determination of the quantity and velocity may be effected by simple substitution of the known values in equation (11).

For instance, assume that in a carbureter of this type, provided with a primary inlet 5-8 inch in diameter (0.3 square inch area), a vacuum of 1 inch of water causes an auxiliary area of 0.05 square inch to be opened.

(A) A head of 1 inch of water is equivalent to a head of 68.284 ft. of air at normal pressure and temperature.

By equation (1)

$V = \sqrt{64.4 \times 68.28} = 66.31$ feet (or 796 inches) per second.
$A = 0.3 + .05 = 0.35$ square inch.
$Q = 796 \times 0.35 = 278.6$ cubic inches per second.

By equation (8)

$Vf = \sqrt{(.00169 \times 66.31^2) - 1.9} = 2.35$ feet per second.

(B) Assume now that, on open throttle, the vacuum within the carbureter is 20 inches of water. The head of air would be

$20 \times 68.28 = 1{,}365.6$ feet.
$V = \sqrt{64.4 \times 1{,}365.6} = 296.5$ feet (or 3,559 inches) per second.
$A = 0.3 + (0.5 \times 20) = 1.3$ square inches.
$Q = 3{,}559 \times 1.3 = 4{,}616.7$ cubic inches per second.
$Vf = \sqrt{(.00169 \times 296.5^2) - 1.9} = 12.1$ feet per second.

Therefore, the air flow has increased $\frac{4{,}617}{279} = 16.5$ times while the fuel flow has increased only $\frac{12.1}{2.35} = 5.15$ times; or but 31 per cent of the former proportion of fuel is present. In other words, had the original

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mixture in (A) been in the air/gas ratio of say 10/1, the high-speed mixture of (B) would be in the ratio of 32/1, which is far beyond the limits of combustibility.

As may be readily determined, no adjustment of spring tension can do more than very slightly modify this tendency toward impoverishment of the mixture, while the addition of various forms of subsidiary springs, becoming operative only at some point of the valve-opening, can do no more than correct the error at one given point and then start, as it were, merely a new scale of errors.

The inherent error of the auxiliary valve is by no means of theoretical interest only. It still remains a factor of so intensely practical effect, despite the remarkable ingenuity that has been displayed in various attempts to correct it, that its elimination would effect an annual saving of thousands of dollars to both manufacturer and user of motor cars through the increased efficiency of the liquid fuel engine.

## IV. THE MULTIPLE-JET CARBURETER

Attempts to correct the error in mixture composition introduced by the increasing air flow have been confined largely to two principal channels. Abroad, the tendency is toward the use of multiple fuel jets, while in this country more attention has perhaps been given to the direct mechanical regulation of the area of the orifice in the fuel nozzle.

It will be apparent from the foregoing treatment of the subject that, in multiple-jet practice, the flow from each succeeding jet is, in turn, amenable to the law of fluid flow as expressed in equation (8). Hence, each succeeding jet, like the subsidiary spring on the auxiliary valve, merely corrects the error at the point where its own discharge commences and then the flow suffers a cumulative error until corrected by the introduction of the flow from still another jet.

It is evident that the use of a sufficient number of jets might be made to reduce the error to very small proportions, and in fact good results have been obtained from such construction. Mechanical complications and the nicety of constructional detail have proven serious disadvantages, however.

## V. THE VARIABLE FUEL ORIFICE

Inspection of equation (8) and the substitution of values therein in the examples cited, disclose that the fuel velocity is in constantly decreasing proportion to the air velocity. In example III, the quantity of fuel discharge has been treated of in terms of fuel velocity. It is evident, however, from equation (10) that the actual fuel discharge is the product of its velocity and the area of the fuel orifice. Hence, it will be recognized that variation of the area of the fuel orifice may be made to compensate for the increasing ratio between the fuel and air velocities. In III-B, for instance, while the quantity of air was increased 16.6 times, the fuel velocity increased only 5.15 times; therefore, to maintain constancy of mixture, the area of the fuel orifice should have been increased

$$\frac{16.5}{5.15} = 3.2 \text{ times.}$$

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The withdrawal of a straight tapered pin from the fuel nozzle increases the area of discharge in direct proportion to the lift of the pin; consequently delicate mechanical complications are resorted to in effecting the desired decrease in the proportional area opened. Properly designed and properly adjusted, there is no reason why this method should not give results approaching accuracy but when we consider the almost microscopic nicety of adjustment necessary to effect accurate sub-division of the minute fuel stream, we realize the practical difficulty of both making and maintaining such adjustments. When we remember, too, that the volume of liquid gasoline is less than 1/8000 of the volume of the air with which it is mixed, it is apparent that regulation of the 8,000 parts would be much more practical than any attempt to subdivide the 1 part.

## VI. A NEW METHOD OF COMPENSATION

It has been shown in Case V that compensation can be effected by the variation of the area of the fuel nozzle. It is equally true that automatic variation of the total air admission area will accomplish the same result with much greater accuracy and without adjustments or mechanical complications of any kind. For this purpose it is necessary to determine the velocity of the air corresponding to any given fuel velocity.

If, by equation (8)

$$Vf = \sqrt{(.00169\, Va^2) - 2gh'}$$

$$Va = \sqrt{\frac{1}{.00169}\,(Vf^2 + 2gh')}$$

or, more conveniently

$$Va = \sqrt{591.71\,(Vf^2 + 2gh')} \qquad (12)$$

The practical application of these formulæ is, perhaps, best made clear by a concrete example. Let us consider a carbureter with a primary inlet 5/16 inch in diameter (area, 0.077 square inch). Let us assume the auxiliary valve to be governed by a spring that will deflect 0.01 inch for a vacuum in the carbureter of 1 inch of water.

(A) Assume that 230 cubic inches of air per second is passing through this carbureter at a velocity of 90 feet per second. By equation (8) the fuel velocity will be

$$Vf = \sqrt{(.00169 \times 90^2) - 1.9} = 3.43 \text{ feet per second,}$$

the vacuum will be $\dfrac{90^2}{64.4 \times 68.28} = 1.84$ inches of water.

The deflection of the valve will be

$$0.01 \times 1.84 = 0.0184 \text{ inches.}$$

The total admission area will be

$$\frac{230}{90 \times 12} = 0.213 \text{ square inch.}$$

The auxiliary area will be

$$0.213 - 0.077 = 0.136 \text{ square inch.}$$

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(B) Assume now that ten times the original quantity of air is demanded.

The quantity of air would be

$$230 \times 10 = 2{,}300 \text{ cubic inches per second.}$$

This air must pass the fuel jet with a velocity sufficient to induce a flow 10 times the initial quantity of the fuel.

As, by equation (12)

$$Va = \sqrt{591.71\ (Vf^2 + 2gh')}$$

the air velocity that will increase the fuel flow 10 times may be expressed

$$Va_{10} = \sqrt{591.71\left\{10(Vf^2) + 2gh'\right\}}$$

Substituting the valves of the present example

$$Va_{10} = \sqrt{591.71\left\{10(3.4^2) + 1.9\right\}} = 263.67 \text{ feet per second.}$$

The vacuum will be $\dfrac{264^2}{64.4 \times 62.28} = 15.85$ inches of water.

The deflection of the valve

$$15.85 \times 0.01 = 0.158 \text{ inch.}$$

The total admission area

$$\frac{2300}{264 \times 12} = 0.73 \text{ square inch.}$$

The auxiliary area

$$0.73 - 0.077 = 0.653 \text{ square inch.}$$

As a practical convenience these equations may be simplified and expressed in terms of fuel velocity as follows:

$$\text{Velocity of the air} = 24.32\sqrt{Vf^2 + 2gh'} \tag{13}$$

$$\text{Total admission area} = \frac{Qa}{292\sqrt{Vf^2 + 2gh'}} \tag{14}$$

$$\text{Vacuum in inches of water} = \frac{Vf^2 + 2gh'}{7.44} \tag{15}$$

$$\text{Total spring deflection} = \frac{(Vf^2 + 2gh')d}{7.44} \tag{16}$$

where $d$ = the spring deflection for a vacuum of 1 inch of water.

By the use of these formulæ the auxiliary-air admission area may be determined for any number of points in the travel of the valve and the walls surrounding the valve may be made to conform to the curve so plotted, thus assuring the permanent maintenance of any desired air/gas ratio without adjustments of any kind.

### RELATION OF VELOCITY TO VACUUM

In all the foregoing calculations the influence of friction and other factors modifying the flow of liquids in a carbureter have been omitted for the purpose of permitting simplified statements of fundamental principles. These modifications are, however, of prime importance, none the less so because their variant values are undetermined. They affect the flow of both fuel and air to such an extent that without giving them due

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consideration, the application of any formulæ expressing the relationship of actual flow of fuel and air would be impossible.

Thus the formulæ herein expressed have, so far, tentatively assumed that the drop in pressure or "vacuum" at the mouth of the fuel nozzle was the same as that within the mixing chamber. Repeated experiments have demonstrated the fallacy of such an assumption, to which indeed must be attributed the failure of many otherwise meritorious devices. Solution of the intricate problems existing between the mouth of the fuel nozzle and the mixing chamber, involving marked physical changes in both the liquid fuel and the air, would be interesting theoretically, but, from a practical standpoint, we are fortunately able to eliminate the effect of these modifying influences instrumentally. This can be accomplished by two structural modifications. First, the control of the auxiliary area directly by the vacuum at the mouth of the fuel nozzle, which construction also presents the further practical advantage of rendering the action of the instrument practically insusceptible to barometric changes. Second, by a slight modification of the curve of auxiliary-admission areas, so that the air velocities are increased a sufficient amount, determined experimentally, to compensate for the frictional resistance offered by the nozzle to the flow of the fuel. Instruments constructed in accordance with the foregoing principles have been found to maintain a constancy of mixture in strict accord with the theory, and it has been determined that the slightest departure from the theoretical curve of admission areas, produces negative results in constancy of composition.

## VARIABLE MIXTURES

If, however, it were desirable to vary the mixture composition for different operating conditions, the proposed method lends itself readily to that end. Thus, the auxiliary areas may be diminished at and near the starting end of the curve, resulting in the richer mixture so often claimed to be necessary for easy starting. At ordinary road speeds the areas may be so calculated that a mixture of high fuel economy will result, while at extreme open-throttle for high speed, contraction of the admission curve will increase the richness of the mixture for the development of maximum power. In other words, the designer has but to determine the range of mixture composition which he considers most satisfactory and construct the admission curve in accordance therewith, knowing that whatever action has been selected will be repeated with invariable exactitude.

## CONSTANT MIXTURE

The results obtained from many different engines by the use of gasoline mixtures of really constant composition have been so pronounced as to be in the nature of a revelation, particularly as regards certain details not ordinarily considered as primary functions of carburetion. Among these it is worthy of note that without exception every engine developed its maximum torque, both at high and low speeds, with a fixed spark advance. There is noticeable also a marked quietness of operation not

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easily explained, unless, possibly, the uniform rate of flame propagation establishes a rhythmical vibratory effect. The objectionable features of fluctuating mixtures are, naturally, minimized. After a full season's running the cylinders of several cars were found free from carbon, while the spark-plug points were clean and the porcelains discolored by heat only. Exhaust gas analysis shows practically no loss through incomplete combustion. The average of 44 samples taken from several different cars under all sorts of road conditions gave 0.43 per cent. CO, while 29 samples yielded no CO.

## DISCUSSION.

C. P. GRIMES.—I think Mr. Browne covered the subject very well in that he omitted at the start the variation of temperature before he attempted his discussion. The problem of temperature and pressure in the carbureter to-day is the most complicated we have to deal with. I think every one knows that a small variation in the temperature of kerosene or gasoline will make a very wide variation in the flow of the fuel in relation to the air. I have found in my experiments that the pressure in the carbureter has far more to do with the economy of carburetion to-day than seems to be generally recognized. I at one time designed a carbureter with a variable throat. I varied the amount of gasoline flowing from the nozzle by varying the area of the throat into which the gasoline was drawn by placing a bob in the center capable of movement along its axis. This carbureter worked out nicely, but I found it was altogether too sensitive to temperature change, and further that the absolute pressure in the carbureter at low speeds was too high to effect proper breaking up of the fuel.

E. B. WOOD.—Mr. Browne will correct me if I misunderstand the paper, which I possibly have. I think his whole theory of carburetion and the peculiar behavior of the carbureter is founded on the assumption that the gasoline level is half an inch lower than the jet, because if you take his first example and cut out the correction for level, which you can do for experimental purposes by simply letting the jet flood, according to his figures, it would give a constant mixture, whereas it very certainly does not. The fault, I think, arises in this manner—it is probable that the air flow does follow the law $V = K\sqrt{2gh}$, but the difficulty is we cannot measure the height H in feet of air. If we measure it with the water gage it is apparently not the real height. Dr. Watson did some experiments in that line. He compared the mean pressure in an induction pipe taken from the manograph (indicator) diagram with that of the water gage, taken at the same point and they were entirely different. I think the fuel follows the $V = K\sqrt{2gh}$ law over a fairly wide range and is under very similar conditions to the water gage which measures the suction.

THOMAS S. KEMBLE.—I have been very much interested in this paper and am glad that we are going to have it in the records of our Society. I have done considerable work with an air valve which compensated according to the principle which Mr. Browne has described, except that

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the valve was operated by the pressure from the mixing chamber and not by the pressure at the fuel orifice. This worked very satisfactorily. It does not seem to me, though, that the real difficult problem which now confronts us in carburetion is the obtaining of the proper ratio between air and fuel, but rather the proper breaking up of the fuel and the proper application of heat so as to approximate as nearly as possible real carburetion.

I cannot understand some of the results that are given in the paper as being due simply to the proper proportions of the mixture, but believe that there must have been some very happy designing which brought good carburetion as well as proper mixing.

The matter of the best results being obtained with a fixed spark, I am unable to understand. A time lag exists in the magneto and at high speed we have a lower volumetric efficiency and consequent lower rate of flame propagation. In view of these facts I cannot see how the same spark setting can be proper for both high and low speed.

C. P. GRIMES.—This is not very technical, but I wish to suggest that the real problem in this commercial enterprise is to provide an instrument that will do so much. An ammeter to measure current will cost $25, a voltmeter about $50, a venturi meter $90. And these meters vary greatly. My grocer paid $250 for some new scales and when I questioned the weight of a purchase his scales were wrong, because, he said, they had to be set for each ten degrees temperature.

A carbureter must measure air and gasoline under all conditions of humidity, temperature and pressure, and yet the manufacturer demands such an instrument for about $10, which must include proper overhead, research and maintenance of the goods sold.

JOHN WILKINSON.—I would like to make a little comment on that spark question. I do not agree with the gentleman at all. We have made experiments for years on the question of power in relation to spark advance. We make motors with small combustion chambers where the distance of the spark point from the flame propagation is about as small as you could get it, and have never been able to find any conditions wherein the increasing speed did not require an increasing spark advance to obtain the maximum power, no matter what the condition of the mixture.

ARTHUR B. BROWNE.—I am aware that I am open to the criticism, in this paper, of touching only one of the problems, and the one that may be considered the minor problem in carburetion. Personally I think that idea has become prevalent, but I believe it to be a mistake that is holding us back in the production of efficient gaseous mixtures and obtaining efficiency from engines.

I did not bring the matter up in the discussion of the paper read by Mr. Chase, but if the gentlemen who have copies of his data sheet will turn to the table they will notice that the chemical composition, the quality of the mixture—I prefer that term—varied from 12.2 ratio to 7.8 during this test as the speed increased. The curves which Mr. Chase showed indicate, to my mind, without carefully calculating them, not only a con-

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siderable loss in volumetric efficiency, but in addition to that a tremendous loss from imperfect combustion caused by overrich mixtures. We cannot maintain, in my opinion, mixtures of varying richness, mixtures richer than the point of chemical composition, without sustaining serious power losses.

To state the problem a little bit differently from what I did in my remarks prefacing the paper, I believe that the problem of carburetion as a whole consists, first, of quantitatively mixing a liquid and a gas, and second, in producing complete vaporization of the liquid in the gas. Then only can you have proper distribution and equal power in the cylinders.

The gentleman spoke of the many variables in the problem of carburetion. It is true; and as I have attempted to state in my paper, they would make an exceedingly interesting study from a theoretical standpoint, if it were not possible to eliminate those variables instrumentally, except the ones that I have mentioned.

Regarding the fixed spark position, I can assure the gentleman that no one has been more surprised at my experience than I have myself. I do not attempt to defend it. I do not even attempt to claim that it is true. I will cite a single illustration of a certain car with a certain carbureter where the spark could not be advanced more than twenty-three degrees on the quadrant without a serious knock. A carbureter embodying the principles outlined in my paper was installed on this car. The spark lever was placed at full advance and the car driven from three miles an hour to its limit of speed with no indication of knocking. Now on that car it was not an accident. Had this condition occurred but once or twice, it might have been accidental. But as a matter of fact it has been observed on every one of fifteen or twenty different makes of cars that I have experimented on. Consequently, while I do not attempt to define its cause, it is certainly an apparent fact up to date.

I have failed to comprehend the criticism made by Mr. Wood that the elimination of the head or vertical distance between the level of the float chamber and the mouth of the fuel jet would give rise to a constant mixture.

The head (h′ in equation 8) is not, in reality, simply the vertical distance between the level of the fuel in the float chamber and at the mouth of the fuel jet. To this must be added the "friction head" imposed on the fuel by its passage through the nozzle. This quantity is subject to constant variation and depends for its value upon the velocity, density and viscosity of the fuel.

It by no means follows, therefore, that a constant mixture would result by maintaining the level in the float chamber identical with the level at the mouth of the fuel nozzle. Could some means be devised whereby the true value of h′ would become zero I would certainly expect a constant mixture to result.

The effect of friction head is so well recognized in hydraulics and so difficult of accurate determination under the conditions of carburetion that I refrained from complicating the formulæ by its consideration and

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hence throughout my paper have referred to the quantity h′ as a mere difference of level.

I have been experimenting with approximately constant mixtures. I say approximately because my work has been conducted very largely on the road, without adequate laboratory facilities, and I have depended for my knowledge of the correct mixtures entering the cylinders on gas analysis of the exhaust. So I say that I have been experimenting with mixtures of reasonable constancy. The results have been very apparent in increased power, which results agree quite closely with pre-determination of gaseous mixtures. That is, the greatest power has been obtained with approximately a twelve- to thirteen-to-one mixture, at the same time securing extreme flexibility and extreme quietness, not on one engine but on many operating with this mixture. The subject has not undergone such development as I propose to give it, and much desirable data are lacking, but it seems that we are opening a new field and that many discrepancies that we now find in motor car operation can be explained and possibly remedied by carbureter modification.

C. P. Grimes.—I was going to say that we have found in our carbureter economy readings on the road, that very often you could tell whether one carbureter is more economical than another by the position of the spark on the quadrant at which the mixture would fire. The chemical analyses that we have made show that no two mixtures will ignite at the same rate.

P. S. Tice.—Practically the whole of the experimental work of my firm has been conducted with a view to producing a simple carbureter, the type alluded to by Mr. Browne—a single air passage and single jet—and we have subordinated our structure entirely to that. But we have found that compensation can be secured by a simple rearrangement of the fuel passage with reference to the air passage; that is, a rearrangement of the simple carbureter, as one ordinarily thinks of it. We use for our air passage a form commonly termed the "reëntrant nozzle" and locate the fuel conveying air passage within that one.

I would like to touch upon the matter of mixture formation as distinguished from compensation; that is, as distinguished from mixture proportioning. We find it of the utmost importance to secure a thorough breaking up of the fuel, a thorough mixing, and as thorough vaporization as can be had. Practically the whole of carburetion is bound up in vaporization; and in order to secure it we have to apply, or have to put into the fuel, a certain quantity of heat, depending on the fuel. There is only one way of getting heat into the fuel. But we can assist in getting heat into the fuel by securing a thorough mechanical breaking up. This can be secured by high air velocities, as the most simple way, to begin, and, of course, permits of transferring very rapidly what heat is available.

I would like to allude to certain things brought out in some kerosene work which we have done. They will illustrate the point, although the difficulties are greater with kerosene than with gasoline. A carbureter of elementary form was used and the heat input necessary to secure complete vaporization of the fuel determined. The motor was run under

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throttle, but the throttling was identical at all points in all the runs. Now this motor was maintained at the predetermined speed and torque, which were the maxima for the elementary carbureter in question, over a very wide range in fuel proportion. The normal consumption rate of the motor under conditions of the test, with complete vaporization, was around one and a quarter pounds of kerosene per brake-horsepower-hour. This consumption was very low. This motor could be made to deliver with the same carbureter, the same power, at the same speed, with a consumption of over four pounds of fuel per brake-horsepower-hour. Of course, the higher consumption was obtained, or rather was necessitated, when the heat input to the fuel was lowered, and vaporization was only very partially secured.

Now then, does it not seem, at this time, if we put the greater part of our attention to the securing of vaporization, that the other end of it, the compensation, will practically take care of itself? Some of us may be able to build the most perfectly compensating carbureter that can be made right now. I do not doubt that it can be done. But even if we do accomplish this result under a given set of conditions, we cannot do it with, say, a temperature change of fifteen or twenty degrees without a corresponding change in adjustment. Suppose we are running on the block with certain temperature and other conditions, and that the temperature alone changes; the whole of the carburetion, so far as *exact* compensation is concerned, will be thrown out by a change of ten to fifteen degrees.

L. V. CRAM.—One problem Mr. Browne did not touch on I have found difficult, when it comes to the motor on commercial work, and that is what the customer will demand in the line of acceleration. Mr. Grimes in a paper at the winter meeting discussed this subject and I wish to call particular attention to the truth of his last paragraph. In this country you must greatly increase gasoline consumption over the best possible economy in order to take care of your customer's requirements in acceleration. On the block I have often adjusted a carbureter for very good work, fair acceleration, and put it in the hands of a user who did not like it because it would not "get away" fast enough.

### RICH MIXTURE FOR STARTING.

ARTHUR B. BROWNE.—Mr. President, in the matter of acceleration I would like to have an expression of opinion. If there is anything that is definitely fixed in the research of the authority of the world, it is the fact that the chemical composition of the mixture plays a part in every function of that mixture. The greatest speed range, the greatest power, the greatest economy, have been determined by various authorities who agree very closely. As Mr. Chase has said, it is noticeable that power, possibly maximum power on the block or on the road, if we had any means of measuring it—can be produced throughout a considerable fuel range. But in these days of soaring prices of gasoline can we afford to use any richer mixture than is necessary to give maximum power? I think President Browne will bear me out in the statement that the Royal

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Automobile Club have determined that about ninety-five per cent. of the power and about ninety-five per cent. of the maximum thermal efficiency occur with a mixture of about 14 to 1. I may misquote the exact figures.

T. B. BROWNE.—15 to 1.

ARTHUR B. BROWNE.—Any departure from that composition towards the side of richness means a loss of fuel. The power curve will probably remain fairly level down to a mixture approximating 10 to 1, and I doubt if much difficulty will be encountered even a little lower than that.

That it is necessary to produce a rich mixture for either starting or acceleration I cannot understand. A mixture of perfect chemical composition is the most inflammable, therefore it is the easier starting; it gives the most powerful explosion, therefore it produces the greatest power effect; it is the quickest burning, therefore we have the greatest speed. Now why has this notion become prevalent that we must have a richer mixture for acceleration? To my mind it seems absurd. I admit the force of the argument of those who bear down particularly on the gaseous character of the mixture—it is the amount of *gas* we get in the mixture that produces results. We may inject liquid gasoline without practical effect, unless it be in the form of exceptionally minute particles constituting a spray which vaporizes in the heat of the cylinders. *Liquid* particles are so slow burning as to be almost wholly ineffective and the *gas* content of the mixture is alone available for the development of power. In starting an engine the failure of the carbureter to give to the cylinders a sufficiently rich mixture is because ordinarily it is cold, the vaporization temperature has not been reached and consequently but a small proportion of the fuel is vaporized and becomes effective as gas. While admitting the necessity for increased temperature and high velocities in effecting vaporization, I really believe that most of our carbureter troubles are due to inconstancy in the relative proportion of the true gases constituting the mixture.

C. P. GRIMES.—I wish to say, Mr. President, that the practical everyday men about me who have tried know that it is an absolute necessity to have a rich mixture for starting on a cold morning and for getting away in a hurry.

The graph of the relation existing between the volume of the mixture before and after combustion starts in a straight line from a ratio of 20 lbs. of air per pound of gasoline up to fourteen. At that point there is a very marked change. The curve continues upward at a greater angle to a ratio of nine and I dare say continues thus to the limits of combustion. This change in volume ratios I believe accounts for the increased power in acceleration given by the richer mixture.

I recall a very interesting experiment that was completed within twenty minutes that will illustrate the folly of maximum power.

| N | Lb. | H.P. | Lb./H.P.-Hr. |
|---|---|---|---|
| 1,000 | 50.5 | 28.9 | .5665 |
| 1,000 | 51.4 | 29.35 | .840 |

In both cases the engine ran fine; trained men could not tell the difference by the sound or action. The figures show that there was ex-

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pended 48.4 per cent. more fuel for an increase of horsepower of 1.557 per cent.

T. B. BROWNE.—I do not carry the exact figures in my head, but Dr. Watson has in his paper to the Institution shown us that we do get with the rich mixture a certain increase of power, beyond that obtained from a mixture producing perfect combustion. And I think it is that rich mixture which you are using in this country, as denoted by the analysis of the exhaust gases, to get rapid acceleration.

I would like to say a word about acceleration. Some of you here seem to be very much more keen on rapid acceleration than we are. Most of our makers set their carbureters on cars for ordinary uses, as apart from those turned out for racing purposes or high-speed work, so that very rapid acceleration is not capable of being attained, with a view to prolonging the life of the tires and also to reduce the fuel consumption. The figures are given in Dr. Watson's papers in our Institution Proceedings, and I would refer Mr. Browne to those proceedings for the exact proportions of the rich mixture giving the greatest power.

J. G. VINCENT.—I would like to say one word about this matter. It is one I have been very much interested in. I think carburetion is blamed a great many times for things it is not responsible for. We all know that valve-timing is more or less of a compromise, especially in the six-cylinder motor. I have run some tests which have proved to me that valve-timing has a tremendous effect on acceleration. I have been working along the line of increasing the torque of the motor below 1,200, letting it take care of itself above 1,200. I conducted one interesting experiment with two motors. One showed nine horsepower more above 1,200 than the other, and the one that had nine horsepower less above 1,200 r.p.m. was ahead of the game always, because the overlap of the suction strokes in getting the high power and great speed absolutely killed the motor for low torque, around 400, the motor speed you usually have when you are accelerating. So that I think investigation along the lines of closing the inlet valves early, especially on the six-cylinder motor, and properly taking care of the intake header, and having the passages as small as you can have them, would get you away from a great many difficulties that you are ordinarily up against.

HERBERT CHASE.—I think Mr. Browne is absolutely right in the matter of a constant mixture actually giving the best results, except possibly at very low speeds, where the quantity of gas remaining in the clearance chamber dilutes greatly the incoming charge. The charge needs to be slightly richer in some cases, but much less rich than some people imagine. I believe that at low speed, and in cranking in particular, a large proportion of the fuel actually goes through the motor without entering at all into combustion. The trouble is that vaporization does not take place; with the low gas velocities atomization is not accomplished. The mixture is supposedly rich but in reality a great deal of the gasoline present remains inert so far as effective combustion is concerned.

T. B. BROWNE.—I would say in connection with that that Dr. Watson found that the rich mixture caused the excessively greater amount of

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carbon monoxide in the exhaust, proving that it was really a rich mixture, and not because of the gasoline globules passing through. It was proved by the proportion of carbon monoxide in the exhaust as obtained by actual analysis.

# PNEUMATIC TIRES

By P. W. Litchfield

(Member of the Society)

The manufacture of pneumatic tires, an industry less than twenty-five years old, has grown until at the present time the value of its product in the United States alone amounts to about $150,000,000 annually.

It has been the practice of automobile and vehicle builders for many years to make as nearly as possible the entire vehicle, but while the pneumatic tire is a component part of every vehicle, no manufacturer of bicycles, motorcycles or automobiles has ever successfully made his own tires, and the number of tire manufacturers has always been relatively very small compared with the volume of the industry.

I do not intend in this paper to go into the story of the process of manufacture of a tire, but to confine it largely to the history of the pneumatic tire design, from the time of its invention in the early nineties to the present time. I wish to point out the causes of the many changes which time has wrought in the design, discuss some of the problems now before us, and correct some of the popular fallacies regarding both the engineering and commercial aspects of the pneumatic tire business.

If we go back to about the year 1890 and look at the means of transportation in vogue, we find that the hauling by self-propelled vehicles on land was confined to the railroads, two smooth parallel rails being carefully laid to form a perfect roadbed to protect the machinery of the locomotive sufficiently to make it a practical commercial proposition. The millions of ordinary roads throughout the country were used for hauling by means of domestic animals only.

At about this time the safety bicycle and rubber tire were developed. This brought to the attention of everyone the simplicity, speed and healthful exercise to be obtained by abandoning the horse and propelling the vehicle by man-power. While the horse could not call attention to the weaknesses of the vehicle which made his work harder and his progress slower, man, when he assumed the duties of the horse, began to analyze. Then began the study and development of the self-propelled vehicle industry of today. The development of the internal combustion motor and of the pneumatic tire to protect the delicate machinery from shock followed by various stages. Automobile engineers have been following largely the development of the machine, while the tire man has followed the development of the tire as a means of protecting the machine. While today the cost of rubber tire upkeep is one of the largest items of expense in the maintenance of a car. it must not be forgotten that it is

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the tire which is put where most of the abuse comes, which does for the car what the steel rail does for the locomotive and makes every road possible.

Let us go back to the man on the bicycle. He soon found out that the solid tire was satisfactory on a smooth road, but when it came to a rough road he could feel the bumps and had to slow down, as the impact of the tire against stones and uneven surfaces was more than he could stand with comfort and more than he could propel the bicycle against with his own power for any length of time. Naturally, his next idea was to get more cushion. This resulted in the introduction of the cushion bicycle tire, which was an all-rubber tire with a hole in the center to allow for more distortion in the rubber itself, the cross-section diameter of the tire being increased from ¾ inch to about 1½ inches. The rider then found he had gained more cushion, but had increased the weight of his vehicle, so that it required more power to propel the bicycle on *good* roads. It was at this time that the pneumatic tire was invented to increase the cushion, decrease the weight and lessen the power consumption of the tire on ordinary roads. Since about 1893 the only tires which have been used on self-propelled vehicles are either solid rubber or pneumatic rubber tires; no other type seems at the present time likely to engage the serious attention of engineers.

As both of the above-named types are being used in larger quantities every day, let us (before passing to the pneumatic) analyze the difference between them and see under what conditions one seems to be superior to the other. This brings us to the question: In a self-propelled vehicle, what are the functions of the tire? They are, first, and foremost, a cushion to protect all parts of the vehicle from the shock caused by the impact against inequalities of the road; second, to provide proper traction, avoiding unnecessary slip. These are the two main functions, and, therefore, the principal thing to be kept in mind in tire design is to satisfactorily accomplish them at as low a cost per vehicle mile as possible, with the least possible consumption of power, and with the least amount of trouble and inconvenience to the driver and occupants. The pneumatic tire depends upon the elasticity or resiliency of a gas, *i. e.*, air, for its cushioning effect, while the solid tire depends upon the resiliency of a practically incompressible solid (*i. e.*, vulcanized rubber). It is needless to say that air is the more perfect cushion and the lighter and cheaper, the cost lying only in the air container. No other *solid* body can compete with india rubber in acting as a cushion by being greatly distorted and recovering its original shape again repeatedly with very little fatigue.

One point regarding rubber must be carefully borne in mind, which is, that vulcanized rubber is practically incompressible; its cushioning effect is only possible by distortion and recovery, and it must be allowed by the designer plenty of room for this action. A glance at hundreds of patents on solid-rubber tires shows that this point has been almost entirely ignored by inventors. Another point frequently overlooked is that the shock may come from almost any direction, owing to varying road sur-

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faces, turning corners, running into curbstones, etc. Many tires and spring wheels carefully designed to take up blows acting directly from the ground vertically towards the rim are utterly unfit to withstand shocks in other directions.

Before selecting between the solid and pneumatic tire, the weight to be carried, the speed to be attained, and the character of the road must be considered. The load to be carried can be worked out satisfactorily on either type. In a solid tire it requires a sufficient amount of properly compounded rubber, and in a pneumatic a sufficient combination of air volume and pressure contained in a suitable retainer. The character of the road and the speed have a great deal to do with the selection of type, as air being a much better cushion than rubber, allows the pneumatic to give much more efficient cushion and traction on rough roads and at higher speeds than is possible for the solid. As far as the efficiency of the vehicle is concerned, the pneumatic would nearly always be chosen as the ideal tire were it not for the fact that in many cases the roads are sufficiently good and the necessary speed sufficiently slow to make the saving in cost per mile on solid tires, due to their longer life, offset the increased efficiency of the pneumatic. Again, the unreliability of the pneumatic due to injury through punctures or blowouts, making attention to it necessary at awkward places and times, often causes the selection of solid tires, as frequently occurs on pleasure electrics for ladies, fire apparatus, mail wagons, etc. In short, good roads and slow speeds are favorable conditions for solid tires; ordinary roads and high speeds for pneumatic tires. The solid tire having less cushion and less motion requires a lower percentage of pure rubber in its composition than the pneumatic, which tends to lower tire mileage cost.

### RUBBER SUPPLY

A lowering of the price of crude rubber will tend to popularize the pneumatic tire, and it is well to bear this point in mind, as the average price of crude rubber will probably be lower each year until it reaches less than one-half its present market price. The selling price of crude rubber in the past has been fixed by supply and demand and speculation, with no reference to its cost of production, but its cultivation on a large scale is changing this condition, and it is probable that in five or six years there will be a sufficient amount of rubber to supply the demand at a cost of less than 40 cents per pound, which alone should save 33 1-3 per cent. in the cost of pneumatic tires. The danger of the rubber supply running out, which was very serious three years ago, causing rubber to advance to $3 a pound, caused successful cultivation to become an accomplished fact, which apparently solves the question of our future supply. It is hoped that the present scarcity and high price of gasoline will in a similar manner be the means of solving the question of the future motor fuel supply.

### THREE TYPES OF PNEUMATICS

To go back again to the man on the bicycle. His experience with solid and cushion tires resulted in the invention of three types of pneumatic

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tires at almost the same time, and these three have been the only ones that have been, or are now, used in any quantities. They are the single-tube, invented by Tillinghast; the clincher, invented by Bartlett, and the wired-on, invented by Dunlop. There was great rivalry between the three types for two or three years, resulting in the supremacy of the single-tube in the United States and the clincher and wired-on types in all other parts of the world. The introduction of quick-repair cements, of single-tube repair shops all over the country, and lower cost of production were largely responsible for the success of the single-tube in this country. The wired-on type is still the most popular in other countries.

Following the pneumatic bicycle tire came the pneumatic carriage tire, and each country developed the type of tire found most popular on bicycles. This was a temporary business, however, because the tires were used on horse-drawn vehicles, they did not have to perform the traction or driving functions, and the speed of the horse was so slow that a sufficient amount of cushion could be obtained from solid tires and metal springs without the annoyance of punctures; hence this type of tire gradually give way to the solid.

Following the pneumatic-tired carriage, about the year 1898, came the automobile with its delicate mechanism and high speed, and with it the demand for a more durable and efficient pneumatic tire. As in the case of the carriage, each country still further developed the type of tire which was most popular and successful on bicycles. American designers went ahead with the single-tube, making it up to 5 inches in size, while England developed the wired-on, and France the clincher (the clincher was also being made by G. & J. and Goodrich in the United States). It did not take very long, however, to discover that conditions were quite different on the automobile from what they were on the bicycle, and the French clincher tire made by Michelin and others soon had all the other types "on the run," and English and American tires were at a discount. The wired-on type, which proved so successful on English bicycles, disappeared in the large sizes, because the one-piece Dunlop rim, which was so easy to fit with an inextensible-edge tire in small cross-sections, was almost an impossibility in large sizes. The single-tube American tire when made of a size and thickness necessary for an automobile could be repaired only at great expense and at a well-equipped repair shop. Roadside repairs were impossible. The clincher type soft bead tire was the only practical one of the three for an automobile, and soon became the standard of the world and was made in all countries. The weaknesses of this type of tire which developed were principally the difficulty of forcing the tire (in the large sizes) over the one-piece clincher rim; the necessity for several tire bolts to keep it from creeping on the rim, owing to the stretching of the bead; its depending entirely upon air pressure to hold it on properly; and when overloaded, or much underinflated, rim-cutting, and if run wholly deflated, destruction in a very short time. To overcome these difficulties several mechanically fastened side-flange and bolted-on type tires were introduced, but they required special wheels.

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special widths and diameters of felloe, were more expensive, and, with the exception of the Fisk bolted-on type, did not make much headway against the standardized clincher tire. The Clincher Automobile Tire Manufacturers' Association had wisely standardized the clincher rim dimensions and insisted on carefully inspecting all rims manufactured, saving to the automobile owners and tire manufacturers hundreds of thousands of dollars, which would have been lost if the unstandardized condition, similar to that which now exists in Europe, had not been remedied.

During five years, from 1900 to 1905, the clincher tire was perfected and standardized. It seemed that it would have no competitor, but the last-named year brought out the invention of two quick detachable rims, the Dunlop and the Goodyear. They were developed to a point that they would fit the same wheels as the clincher rim, and by reversible rings, take either the clincher type of tire or the wire-bead type. These rims overcame, first, the difficulty of stretching the tire over the clincher rim, which was so difficult in large sizes; second, with the removable side ring the tire could be made with an inextensible bead, making it free from creeping by the use of only one bolt on the valve stem, instead of several at intervals around the tire; third, the beads being always against the rim, the inner tube was not as liable to be ruined, in case of puncture, by getting under the beads, and, fourth, a wired-on type could be used with the flanges turned outward, instead of hooked in, making rim injury to the tire less likely in case of overloading and underinflation. The flared-out side ring also made it easier to mount and remove the tire from the rim. This quick detachable type of rim became, a year or two later, the American standard and the wire-bead type of tire began to grow steadily in popularity.

The introduction of this wire-bead straight-side tire met with considerable opposition from the manufacturers of clincher tires, and in meeting it they introduced the quick detachable clincher type. This was a combination of the inextensible wire-bead and the clincher hook. This tire overcame the disadvantage of forcing the tire over the rim, and the pinching of the inner tube when deflated, but possessed no advantage over the straight-bead type, and had the disadvantage of having an extra amount of unnecessary material in the beads; a smaller air volume in the tire; being more difficult to apply and remove from the rim; the addition of the hook bead performing no useful function whatever, except that of a filler to enable its use upon a clincher rim. It would seem inevitable that this type of tire will soon give way to the straight-side type. This narrows down the principal types of pneumatic automobile tires to two forms—the soft-bead clincher tires (to fit the one-piece rims) and the wire-bead straight-side tires (to fit the quick detachable rims). This brings the historical development of the pneumatic tire down to the present time.

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## VULCANIZATION

I would now like to discuss some of the differences between the principal pneumatic tires now in the market. Let us first take up the subject of vulcanization. Vulcanization is the chemical change which is caused by the action of heat and time upon the mixture of rubber and its chemical compounding ingredients, transforming it from a plastic dough to a resilient and reacting solid. In order to get a properly vulcanized tire extreme care must be used as to the materials used in compounding, in regard to both quality and amount, and also as to time, temperature and conditions under which the vulcanization takes place. A tire revolving constantly along the road, carrying the weight of the car, and each moment changing its shape and recovering, generates a great deal of heat. This action of heat carried on for a considerable time has a tendency toward affecting the vulcanization. Therefore, all high-grade guaranteed tires are usually compounded so that they take a very long time to vulcanize. This increases the cost of manufacture. Many unguaranteed tires are so compounded that they vulcanize quickly, saving from one-half to three-quarters of this time, in order to cut down the cost, but the heat generated along the road tends to overvulcanize these tires and they are apt to separate and blow out after a much shorter mileage on this account. The three methods of vulcanizing now in use among the tire manufacturers are popularly known as, first, the one-cure wrapped tread, as examples of which may be mentioned the Fisk, Empire, Ajax and the G. & J.; second, the unit molded type, examples of which are the Republic, Goodrich, Michelin and Diamond; third, the two-cure wrapped tread, examples of which are the Firestone, Morgan & Wright and the Goodyear. Michelin and Diamond tires were formerly made by the third process, but recently have been made by the second. In the one-cure wrapped tread process the tire is completely built over an iron core, wrapped with fabric and put into an open steam boiler and vulcanized in one heat. In the unit molded process the tire is completely built upon an iron core, then put in an iron mold and vulcanized under hydraulic pressure in a press or open steam vulcanizer. In the two-cure wrapped tread process the carcass of the tire is built over an iron core and vulcanized in a mold, the same as in the unit molded type, but not entirely cured. It is then removed from the mold, buffed and cemented and the tread rubber applied and given a second vulcanization. With the Morgan & Wright and Firestone tires this second vulcanization is done while the tire still remains on the core, while in the Goodyear process the tire is inflated by means of an air bag on the rim; in either case after the tire has been cross-wrapped the second cure takes place in an open steam vulcanizer. Each of these three methods of vulcanization has its enthusiastic supporters. Those who use the first two methods claim that they obtain a more perfect vulcanization. They are undoubtedly cheaper in first cost. Those manufacturers using the two-cure process believe that the vulcanization is more uniform throughout the tire and that there is

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sufficient increase in quality and durability of the tire produced to warrant the extra initial cost.

### FABRIC

Another difference in pneumatic tires is in the style of fabric used, there being two distinct types upon the market, the close-woven fabric tire and the cord tire. Nearly all tires are of the close-woven fabric type as they are more durable, easier to repair in case of injury, and can be operated at a much lower cost per mile. In driving a car considerable power is consumed by the flexing of the pneumatic tires, and it has been found that this loss can be reduced largely by using parallel cords instead of woven fabric, as much as 25 per cent. of the power sometimes being saved. The cord construction also permits greater speed and makes an easier riding tire than the square woven type. It is, however, a much more difficult tire to repair and in practice does not work out at as economical a cost per mile as the close-woven type. Its power-saving factor makes it desirable on electric vehicles, where the radius of action is limited by the capacity of the storage battery used. In a fuel economy test with a gasoline car the mileage in many cases could be increased from 15 per cent. to 20 per cent. by substituting cord tires for the square woven-fabric tires.

### SIZE

The next point to consider is the size of the tire. In the pneumatic tire the load is carried by an air cushion, and the amount of the load carried depends upon the combination of the volume and pressure of air used. For a given weight of car it follows, therefore, that the larger the volume of air in the tires the less inflation pressure required, while the smaller the tire the greater the inflation pressure necessary to carry the load. Tires should be large enough to carry the load with very little flattening of the tire, say not over 14 per cent. of the sectional diameter at an inflation pressure which will give sufficient cushion to the vehicle. For instance a car may be equipped with 32 x 3½-inch tires and be of such a weight that it requires 90 pounds pressure in them to properly carry the load and avoid such excessive flexing of the tire walls as to cause rapid breaking down of the casing. This pressure would make the tire so rigid that the tendency would be to reduce the air pressure in order to get sufficient cushion, which would cause the tire to give short mileage. While, if a 33 x 4-inch tire were used on this car, the air volume would be enough larger to permit the successful use of a lower air pressure, increasing both the cushion and the durability of the casing. The inflation pressure which you see embossed on the casings are the pressures which the tire manufacturers recommend as necessary when carrying the maximum load for which the tire is guaranteed. There is always a certain amount of leaking of the air through either the pores of the rubber or through the valve connections, which causes the inflation pressure in the tire to be greatly reduced. It is frequently the case that a 32 x 3½-inch tire will start out with 70 pounds air pressure and not be reinflated until the pressure is down to less than half this amount. Need-

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less to say, the volume of air being constant, the ability of the tire to properly carry the load is reduced constantly as the pressure decreases. This shows the necessity of frequently testing the pressure with a gage and keeping the tire up to the required pressure. Whatever effort the tire manufacturer makes to put mileage into a tire is of no value unless the air pressure is maintained by the user. The extra power consumed by the use of the larger tire is so small as to be a negligible quantity in present-day cars. It is also to be noted that the larger the cross-section of the casing, the greater the amount of tire wall which comes into action, which reduces the fatigue of the rubber and fabric and lengthens the mileage which the casing will give.

### FILLERS

The use of tire fillers is another question which has commanded the attention of automobilists, owing to the extensive advertising carried on by tire filler companies during the past year. A pneumatic tire casing is designed for use with compressed air; when it receives a blow or shock from an obstruction in the road, the blow is distributed all over the casing, owing to the support of the perfectly fluid air-cushion behind it, the tire absorbing the blow, turning it aside, with very little injury to the casing, except in very severe instances. When a filler is used, the blow is localized in the immediate proximity of the point at which it is received, and the strain falls in one place, thereby weakening the tire. Constant repetition of these blows causes the casing to gradually disintegrate and wear out. The fillers add considerably to the weight of the car, require a great deal more power to drive the car, and do not absorb the shocks to nearly the same extent as in the case of air. Air retains its resiliency and is as perfect after being in use a year as when put originally into the tire, whereas the original maximum resiliency of a tire filler decreases gradually. The detrimental effect of the fillers was shown by the withdrawal of the tire guarantees as well as car guarantees by nearly all the principal manufacturers when tire fillers are used. Another disadvantage of the filler is that as the casing stretches, the filler, being a solid body, does not follow up the casing with a constant pressure, whereas air, being a gas, maintains its pressure continually, regardless of the flexing and stretching of the casing. The casing cannot carry the load for any considerable period without the required pressure in the case of a tire filler any more than it can with air. Substitutes for air other than solids have been used, especially different forms of gas. The use of these various gases as proper means of inflation has been questioned by the tire manufacturers, not because they are chemically injurious to the rubber, but because they filter through the walls of the inner tube much more rapidly than air, consequently reducing the inflation pressure. Carbonic acid gas at usual riding temperature will leak through the walls of the inner tube many times faster than air. It has even been demonstrated that with air, the oxygen seeps out much faster than the nitrogen. The disadvantage of the carbonic-acid-gas-inflated tire is that the user does not realize how fast the pressure is reduced

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and does not restore it quickly enough. When sufficient care is used, and the inflation pressure is frequently tested, there is no reason why carbonic acid gas should not be as satisfactory as air.

### RIMS

Before closing I would like to touch upon the subject of rims for pneumatic tires, as it is of the greatest importance to the tire that it be fixed upon a properly designed rim. With clincher tires especially the exact contour of the hooks is of great importance, as it takes only a very little variation from the standard to completely ruin the tire. The proper design for the width between clinches on a clincher tire has been standardized at 60 per cent. of the nominal cross-section of the tire. It is the writer's opinion that the proper dimension for the width at the heel of the bead for the straight-side wired-on tire is 66⅔ per cent. of the nominal cross-section of the tire, flaring outward from the heel of the bead. The less the required flexing of the casing when the tire is overloaded or insufficiently inflated, and the larger the supporting surface given by the rim to the tire where the flexing occurs, the less the tendency toward rim-cutting. The ideal rim would give continuous support to the tire, especially where the tire leaves the rim on the sides. Split and open side rings should be avoided as far as possible. When split rims are used, it is also absolutely necessary that they be in perfect alignment.

## DISCUSSION

P. W. LITCHFIELD.—It has been a great pleasure to me on this trip to meet Mr. Dunlop, the inventor of the Dunlop pneumatic tire. (Applause.) The small amount of time in which the pneumatic tire business has been developed is demonstrated when the inventor and the father of the whole industry sits before us.

PRESIDENT MARMON.—After this paper that tells us so clearly the condition of the tire industry, it seems to me to be particularly fitting to ask the father of the pneumatic tire industry to tell us how he made the first tire. Mr. Dunlop, will you please do so? (Long continued applause.)

J. B. DUNLOP.—Mr. Chairman and gentlemen: I esteem it a very great honor to be asked to say a few words on the invention of the pneumatic tire. A great many statements, or rather misstatements, have been made regarding the invention of the pneumatic tire, which I think I shall not refer to at present. As we say in Ireland, half of the lies that are going are not true. (Laughter.) I shall therefore confine my remarks to facts relating to the invention of the pneumatic tire.

I shall not attempt to criticize the very interesting and comprehensive paper that I have had the pleasure of listening to. I am sure it would take more than an hour to do so in detail. I will simply state how I came to invent the pneumatic tire.

I always realized the importance of reducing traction or propulsion as well as vibration on land and water. I had given a considerable amount of attention to the designing of boats and sails. I had been

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thinking for many years as to the best methods of reducing friction and vibration on roads. I thought for a long time of flexible steel bands suspended round the periphery of a wheel, but I was afraid steel would not stand the continued bending. As a matter of fact after I invented and made the pneumatic tire I patented and made a spring wheel which on average roads was on the whole a shade faster than the pneumatic. It was tested several times against the pneumatic tire by allowing two bicycles to run side by side down a gradient. The former was the faster at high speeds and the latter at low speeds. The riders were changed and the results were the same. My son rode the spring wheel (a front one) daily to the Blackrock College and it was a center of attraction there, but the rim broke after having been ridden for about fifty or sixty miles.

I fitted double flexible suspension steel rims to a tricycle which I rode for about 200 miles. It was a luxury to ride. From an early age I always had an idea of something of a resilient nature that would flatten out so as to increase the area supporting the weight of the rider and vehicle. That was the idea which at last led to the invention of the pneumatic tire.

I have often been asked what made me think of the pneumatic tire. Nothing surprises me so much as to think that I was so slow in thinking of it (laughter), although the idea came suddenly at last. Scarcely anything surprises me so much as to think that no one else ever thought of or attempted to make a practical pneumatic tire. When I was five years of age an Edinburgh gentleman invented a pneumatic tire. A set of these tires was actually made and fitted to a carriage belonging to the Duke of Northumberland. The tires were designated elastic bands. They were actually run on the road a few times from the Duke's domain to a neighboring village near London. The tires were not made by the inventor. They were made by one of the largest rubber manufacturing firms in England, perhaps the largest in the world, and they were fitted by a coach-building firm under the supervision of Mr. Davis, who is still alive and whose son Frank is the sales manager for a large firm of rubber and tire manufacturers. These tires were far from being a practical success. They were forgotten and no one seemed to have heard of the invention until about two or three years after I had the pneumatic on the road.

Every one knows that the speed of the pneumatic tire is largely due to its resiliency, but it is very peculiar that the most resilient pneumatic tire ever made was the slowest. That tire was made and extensively advertised in America. The cover or inexpansible jacket was made of a single layer of unwoven threads running across the tread. The absence of the usual longitudinal or circumferential threads at the tread impaired the rigidity of the tire in a fore-and-aft direction. To obtain great speed in a pneumatic tire it is absolutely necessary that at the tread it should be very resilient in a direction radial with the wheel and as rigid as possible in a fore-and-aft and in a lateral direction. Although America produced the slowest tire, she also produced the

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fastest. It will be within the recollection of many how the people went mad with excitement at the introduction of the Palmer cycle tire in England in 1893; and how it carried all before it. It was a single tube tire, difficult to repair. The inexpansible jacket was composed of two layers of parallel threads crossing each other in a diagonal direction.

Comparing the pneumatic with a solid rubber tire, apart from resilience, the former has incomparably greater surface rigidity, circumferentially and laterally. For example, let us take say an inch cube of rubber and stand on it; supposing it becomes compressed to half an inch in thickness, obviously it will expand in all directions horizontally, by nearly a quarter of an inch. Therefore the edges of the rubber creep outwards and cause friction. When the pressure is removed the edges creep inwards and the rubber resumes its normal form. This is what takes place in each portion of a solid tire as it turns round with the wheel and becomes compressed between the rim and the road. With the solid tire there is always a hump or an increased quantity of rubber in front of the center of the area bearing on the ground. This hump is increased when riding up hill; the weight of the rider and machine causes the wheel to slide sensibly backwards or downwards and the grip of the road drags the surface of the rubber upwards and thus causes the increased hump in front. As the wheel leaves the road the tire behind the central point resumes its normal form and so causes friction. With the solid tire one is always, as it were, riding up hill, even on the level. The pneumatic tire, irrespective of resilience, is quite different from the solid. Its cover or jacket for resisting the air pressure, being composed of cloth covered with rubber, is comparatively inelastic or inextensible and when the tire is inflated the cloth is always under tension. Therefore any point on the surface of the tire is always practically the same distance from any other point, whether these points are in contact with the road or not. The cloth where the tread is resting for the moment on the road and becomes flattened, restrains the rubber, and prevents it from expanding. The pneumatic tire coming into contact with the ground surface flattens and rolls out but does not expand as rubber does. Each portion of the tire in succession comes down and momentarily touches the road and leaves it again without rubbing while in contact therewith. For that reason it was predicted that the pneumatic tire would be faster than the solid on all surfaces, however smooth. Before the pneumatic was invented, rubber tires had been made large, and though they lessened vibration considerably, were found to be very slow, due to the friction referred to. Therefore, racing tires were made very small, about the thickness of my little finger. Before the advent of the pneumatic large sums of money were expended by manufacturers in order to secure the best "riders." If manufacturers had realized the importance of horizontal rigidity in the tire tread they would have made the solids rather thin and broad, say about half an inch thick and five-eighths or eleven-sixteenths broad. The first manufacturer to adopt such a tire section would have caused no slight sensation.

The foregoing are some of the observations made and some of the

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ideas entertained before I thought of making an air tire. When I proposed to make a hollow tire of large diameter which would be extraordinarily fast, every one said that the "idea was absurd." They said that "any one might know that a big tire could not be fast." "There would be too much of it on the road." "What does he know about tires? He has never ridden a bicycle." "He knows something about horses but nothing about bicycles." "I fear he is going off his head." "Why would he lose his time making a bicycle for his son? Why not buy one?"

When solid tires were in vogue no veterinary surgeon would be seen riding a bicycle, because that was supposed to be against the interest of the profession or the horses. There were no rubber or cycle factories in Ireland at that time

In 1887 I bought a little boy's tricycle for my son, then ten years of age. The tricycle had plain bearings and was steered by means of a rack at the right hand side. I told him that I could make a bicycle or a tricycle that would be very fast. I explained to him, as best I could, how the tire would intercept vibration before it reached the rim of the wheel and how it would yield to stones and other elevations on the road. After this he complained of vibration on several occasions. He found the little tricycle was very slow on rough roads, especially on the "square sets," between the tram rails. He got his mother to intercede for him so that I might make tires for his tricycle. On one occasion while I was examining a thoroughbred horse for soundness and passing my hands cautiously down over the hocks, I felt a little hand gently pulling the hem of my garment and a voice saying, "Papa, come and make the tricycle." The boy had been in the habit of frequenting the people's park after school hours and sprinting with other boys. Like most other boys he did not mind vibration, except that it made his tricycle slow.

About the end of 1887 I cut a piece off the end of a plank and made it round in the form of a disc. The disc was about fifteen inches in diameter. I then went to a rubber shop and purchased a piece of finest quality sheet rubber, 1/32" thick. I cut the rubber in strips, made an air tube of it and placed the tube around the rim or periphery of the disc. I procured a piece of nice thin flexible linen, the remnant of a lady's dress. A supply air-tube was made of very fine tubing then in common use for children's feeding bottles. I covered the air tube with the linen cloth and tacked the cloth in a temporary fashion to the edges of the wooden disc. I used my son's football pump to inflate the tire. Having completed and inflated the tire, I brought the disc and tire out of my house into the business yard. I took also a solid-tired wheel. There happened to be in the yard at the time my valued and experienced assistant, John Calwell, M.R.C.A.S., my handy man, and a coachman in the service of Messrs. Greaves, celebrated spinners, well known in America. I asked the three men jocularly, which of the tires they would consider the faster? Mr. Calwell said, "Oh, the small tire, of course, would be the faster." I said, "Let us try." I trundled the disc and air

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tire along the yard and it went bang against the gate and rebounded back a considerable distance. I then tried the solid tire and it scarcely went as far as the gate. My assistant said I must have put more force into the big tire. I asked him to try them, and then he admitted that the large tire went very much faster than the solid. The coachman told his employer that he saw a wheel in Mr. Dunlop's yard that went faster the farther it went. He happened to be standing at the lower and rougher end of the yard and imagined that that was so.

The next thing I did was to remove the solid tires from the driving wheels of my son's tricycle. I then procured two long strips of American elm, 3" x ¼", bent them in the form of hoops and secured them to the outside of the driving-wheel rims. I then made two air-tubes out of fine sheet rubber 1/32" thick. I cut the rubber into strips of suitable dimensions for the air-tube and joined them with rubber solution. After the surfaces to be joined were scraped I rubbed in a little naptha, then a thin coat of solution and also other two coats of ordinary solution. I was particular to see that my hands were quite clean before rubbing in the solution, the first coat being well rubbed in with my finger. Where the pieces of rubber overlapped I was careful to taper the corners by holding the scissors at a considerable angle. I then surrounded each air-tube with a jacket of Drogheda linen. The linen jacket had flaps to secure it to the wooden rim by means of solution. The linen cloth between the rim and air-tube was very thin, in order to prevent a "hinge" at the side of the tire; its only function being to prevent the air tube from being blown in between the edges of the wooden rim and the outer cloth or flaps. Later some tire firms went under in consequence of not providing this necessary strip of linen. The linen jacket was built up and joined with solution.

The linen jacket was cut about four inches shorter than the calculated circumference of the tread of the tire; this was done in order to have the circumferential threads tense at the tread and so give the fore-and-aft rigidity required for great speed, due allowance having been made for the cloth stretching when the tire was inflated. I was also very careful to avoid all "hinges" (an abrupt termination of the ends of cloth or rubber) and to see that all moisture was excluded, as these would have rendered the tire a practical and commercial failure. No one with any knowledge of tire construction would dream of having hinges or employing stitches, lacing, or rivets at the flexible portion of the tire not in contact with the rim. Each one of these would be fatal to the success of a tire as they proved to be in 1846 and in the nineties. I am sorry time will not permit of my going into the matter of textiles for the covers of tires; mistakes were made in that connection with disastrous results in England, United States, Canada, France, Belgium, Germany and Holland.

I used no tool but a pair of scissors to cut the cloth and rubber; the solution was rubbed in with my finger. The linen jackets were covered with fine sheet rubber 1/32" thick, two layers of same at the tread of the tire. The rubber was made firmly adherent to the cloth by

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means of solution. On the night of February 28th, the tires being finished and dry, my son rode the tricycle out of the yard in order to test it thoroughly at a quiet hour. He was instructed to ride as fast as he could over the rougher portions of the street, especially over any patches of newly laid macadam he could find. It was a bright moonlight night and strange to say there was an eclipse of the moon that night (applause), so there is no doubt about the date.

A MEMBER.—What year, Mr. Dunlop?

J. B. DUNLOP.—1888. I did not patent the pneumatic tire until July, 1888. When my son returned after a long ride through many streets, he described the tricycle as being "grand." The tires appeared to hold the air all right and there was not a scratch on the rubber cover.

About two months after this I purchased a bicycle more up-to-date, but without driving-wheels. I built the wheels myself. Seeing that the broad rims and tires stood up so well and were free from any objectionable side-roll, I ventured, this time, on rims two inches broad. The same rubber was used over again, with some additional. The corners of the strips of rubber were tapered off by means of a sharp wet knife. I had the wheels built and the tires finished about the beginning of the following July.

About the beginning of November, same year, I fitted tires to a bicycle built by Mr. R. W. Edlin, of Belfast. I provided and grooved the rims for the bicycle. Seeing that the last tricycle stood up so well, I ventured on smaller rims, 1⅝", and smaller tires, 1¼" inside diameter. The air-tubes were made to my order by an Edinburgh firm. They absolutely refused to make an air-tube for me until they were informed by their Belfast agent that such air-tubes were actually made and in use.

Now, gentlemen, I shall not take up your time much longer. I took out several patents but shall not refer to these at present. I was the first to patent or protect the endless wire. Mr. Welch was in front of me but did not mention an air tire in his provisional specification.

His air tube was made of cloth and rubber. There was only one such tire made. It was made by Capon Heaton, Birmingham, and was never fitted on a wheel or run on the road. My original air tubes have up to the present not been altered. The thickness of the rubber is the same.

This is the first time I have been to America and I am now in my seventy-fourth year. I have always been rather delicate and have not felt inclined to travel much. If I had not paid particular attention to the laws of health I think I would not have been here today to enjoy your hospitality. Our little party seem to have got on very well with the Americans. One gentleman told me before we landed at New York, "But for your bunch of boys, we should have been a dead crowd on board." I have experienced nothing but kindness and pleasure since I came to your country. I can assure you I feel it a very great honor to come here and address such an important meeting. So many erroneous statements emanating from London have been made that I feel it a very great privilege to come here and state the truth before such an

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important audience in such a great and progressive country as America. (Great applause.)

PRESIDENT MARMON.—It was quite a treat to all of us. Are there any comments on the paper of Mr. Litchfield or on Mr. Dunlop's remarks?

### COMPARATIVE EFFICIENCY OF TIRES

A. J. SLADE.—Mr. President, Mr. Litchfield made some reference to comparative efficiencies of pneumatic tires with a close woven fabric and with the cord fabric, and also with reference to pneumatic tires having a filler. Can he tell us the comparative efficiency of the solid rubber tire, the pneumatic with the close-woven fabric, the pneumatic with the cord fabric and the pneumatic containing the filler compound? Take, if you like, as a typical example, a vehicle weighing 5,000 pounds and running at a moderate rate of speed; in other words, a light commercial vehicle running at say fifteen miles an hour and weighing 5,000 pounds.

P. W. LITCHFIELD.—That question cannot be answered by the percentage of efficiencies, because the close-woven fabric tires themselves will vary a great deal and the solid tire will vary and the cord fabric tires vary. In fact, sometimes we get cord tires that do not give us an efficiency of square woven tires, and sometimes we get solid tires that give us the same efficiency as pneumatics. I can show you a great many answers, tests from different sources, at different times, and you can draw your conclusions from those. But as to stating the relative efficiency of several fabric-type tires, that cannot be done, because there are so many variations in tires of the same type.

A. J. SLADE.—I was trying to find out what the probable difference in current consumption would be on an electric vehicle, as between the solid tire and the pneumatic tire. In looking through the S. A. E. data sheets I find some brief reference to the subject, but it was not up-to-date and not very complete. I thought perhaps Mr. Litchfield could give us some further enlightment on the subject.

P. W. LITCHFIELD.—I would be very glad to show you our tests and so forth on that matter. As a matter of fact, a cord tire can be made to give greater resiliency and consume less power than any square woven fabric tire can be. On a perfectly smooth road, without any obstacles, you can get almost the same percentage in a solid tire, properly compounded, as with a cord tire, although not quite. The relative efficiency varies greatly with different road surfaces.

C. H. TAYLOR.—Do you think the cord tire would be less liable to stone bruises on the side walls?

P. W. LITCHFIELD.—I think there would not be very much difference.

CHARLES WHEELER.—Mr. President and gentlemen, as a consumer of some thirty or forty thousand pneumatic tires on the other side annually, I am interested in all questions of running costs. I would like to ask the author's attention to the clause dealing with fabric. There is apparently a slight inconsistency. I say apparently, because there is a possible explanation. The author states that the close-woven-fabric tires are more durable and can be operated at a much lower cost per mile. Further on,

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the cord construction "in practice does not work out at as economical a cost per mile as the close-woven type." Now the concluding paragraph, to quote the clause, reads as follows: "In a fuel economy test with a gasoline car the mileage in many cases could be increased from 15 per cent. to 20 per cent. by substituting cord tires for the square-woven fabric tires."

Now if the first statement holds good, that the close-woven-fabric tires can be operated at a much lower cost, I presume the explanation is that even with the credit to be given for the increased mileage obtained by substituting cord tires, the net result is still in favor of the close-woven fabric. Is that so?

P. W. LITCHFIELD.—I think the experience in this country up to date has been that the cost per tire mile is lower with the close-woven fabric. The cost of upkeep of the car and of fuel is lower with the cord tires.

CHARLES WHEELER.—That is what I presumed would be your reply. Now what I should like to ask Mr. Litchfield is this: Would he modify that opinion if he had to pay, as we do on the other side, forty-two cents per gallon for gasoline?

P. W. LITCHFIELD.—I do not know just where the point comes, but there is undoubtedly a point where the cost of gasoline would be so great that it would be cheaper to use the cord tire and pay the higher tire mile cost in order to get the lower cost of total car maintenance. I do not know whether it is at 21 cents or 42 or 62. It would be very hard to answer that, but undoubtedly with the higher cost of fuel and the lower cost of rubber, the saving brought about by cord tires would play an important part in the type of tire selected.

# Wire Wheels for Pleasure Cars

By GEORGE W. HOUK.

(Associate Member of the Society)

The object of this paper is to give a brief history of the wire wheel as developed in England and its adaptation to the American automobile for American roads.

Being associated with the motor industry abroad from its inception I came to America in 1909 to follow the same vocation. Being in a position to draw comparisons between the American and foreign-built cars, my attention was first drawn to the enormous tire expense when American road conditions were much in favor of the tire as compared with English and French roads, by reason of the hard and flinty surfaces of the foreign roads compared with the soft and springy condition of the American roads. Rarely I found a tire worn out—in most cases it was a rupture caused by a blow, thus weakening the fabric of the tire, resulting in a blow-out. Abroad a tire is usually worn down to the last layer of fabric before giving away, this being caused by the sharp flints that cover the surface of the roads.

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I then began to carefully study the unsprung weights of American cars compared with foreign cars. I found the greatest difference lay in the wheel equipment. I returned to England to find that wire wheels were attracting attention through their merit over wood wheels as tire savers, coupled with their great strength to resist side slips and the ease with which you could change a deflated tire for an inflated one by carrying a spare wheel.

Having known the firm of Rudge-Whitworth, Limited, of Coventry, for a number of years as builders of wire wheels, I found they began in 1905 by making a set of fixed wire wheels for a 90-H.P. Napier racing car, these wheels embodying their well-known principle of dishing the wheels; that is, making the outer set of spokes very much coned, the inner set nearly straight and so arranging the tangent that the inner spokes took nearly all the drive. These wheels first proved their efficiency in the Gordon-Bennett trials in Ireland.

In 1906 Mr. Clifford Earp, at Ormond Beach, drove the last 60 miles of the 100-mile race with one rear tire and nine spokes missing, at an average speed of 99 miles per hour, winning the race. Having found the construction efficient for resisting lateral strains, caused by skidding around corners under high speeds, early in 1906 they began to manufacture and commercialize the detachable wire wheel. In the hands of the public much useful information was obtained by careful attention to the smallest details during a period of three years. Nineteen hundred and nine found the Rudge-Whitworth Company devoting one-third of their enormous factory to the manufacture of detachable wire wheels.

As the wire wheel became a factor in the trade many arguments arose as to its superiority over the wood or artillery type of wheel. A series of tests was carried out at the laboratories of the Rudge-Whitworth Company. The method of testing was by steady pulls to find out the lateral as well as vertical strength. These showed such overwhelming superiority of wire over wood wheels that makers of wood wheels denounced this method of testing, saying it did not represent anything like the actual conditions to which a wheel is subjected while on a car. So the impact test was suggested by Mr. J. H. Lester, a serious student of automobile technology. Until the first series of impact tests was completed it was expected that the intense lateral rigidity of the wire wheel would show worse results than the wood wheel with its elastic yield. Quite the contrary was proven, wire wheels showing up much better than the first-class wood wheels. When weight was taken into account the wire wheel's superiority was incontestable.

A number of members of the Society of Automobile Engineers were present at the Rudge-Whitworth Works in Coventry, November, 1911. The test carried out at that time was on an English artillery wheel, made from oak. The results were so overwhelmingly in favor of the wire wheel that some of the members did not feel that the English artillery wheel was as strong made of oak as the American wheel made of hickory. Rudge-Whitworth procured samples of the best American hickory wheel,

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made by one of the most reputable makers in this country, the wheels being 34" x 4¼". The wire wheel complete with inner hub weighed 92¼ lbs.; the wood wheel 136¼ lbs. The pendulum bob weighed 450 lbs. The pendulum was pulled back at different distances up to 6 feet and released. The tires were inflated to 80 lbs. pressure.

An equal number of blows were struck, resulting in the complete destruction of the wood wheel, while the wire wheel was still in condition to be used.

Wire wheels show a great saving in tires. Many claims are made why this is so. Taking them in the order they would appear to be:

*First—Weight:* A 36" x 4½" R.-W. wire wheel with Houk Q. D. rim, weighs 57¼ lbs., inclusive of the inner hub, the hub weighing 23¼ lbs., the spokes 5 lbs., the rim and nipples 29 lbs. The same size American hickory wheel with demountable rim weighs 101¼ lbs., wood felloe 5 lbs., spokes 9 lbs., felloe band 21 lbs., rim 36½ lbs., wedges and nuts 7 lbs., hub 22¾ lbs. Therefore, the excess weight of the wood wheel as compared with the wire wheel is found at the periphery of the wheel, thereby inducing flywheel effect at high speeds, producing a gyroscopic action and giving very little relief to the tire when coming in contact with road obstructions. This may be said to have a very serious effect on tires. In addition, the double thickness of felloe band and rim, backed by the wood felloe, retains the heat, so detrimental to tires, while the seventy spokes and naked rim of the wire wheel radiate the heat.

*Second—Resiliency.*—The resiliency in the direction in which the load is carried may be said to relieve the strain on the tires in both starting and stopping. Actual figures showing tire saving are very difficult to obtain, as pneumatic tires are extremely variable in their performances. However, we have a concrete example in the Daimler Company's hiring department in London. Fifty tires were tested on wood wheels and fifty tires on wire wheels, attached to identically the same type of cars. The wood wheels traveled 102,524 miles, an average of 2,050 miles per tire. The Rudge-Whitworth wire wheels traveled 172,731 miles, an average of 3,454 miles per tire. This clearly shows an increased mileage of over 70 per cent., or what is equivalent to a reduction in the tire bill of 40 per cent.

The growth in Europe of the use of wire wheels for both pleasure and racing cars is conclusive proof that the wire wheel has come to stay. From the day of the Gordon-Bennett trials in Ireland to the ruling out of detachable-wheel cars by the Grand Prix authorities because of an undue advantage enjoyed thereby, to the subsequent Grand Prix race in which 31 out of 36 cars were detachable-wire-wheel equipped, to the present day when more than 60 per cent. of all European and British production of motor cars is detachable-wire-wheel equipped, to the condition here in the United States to-day, when all leading makers of motor cars are offering as optional equipment the detachable wire wheel, is a period of about seven years.

The fundamental reasons for this sure and steady progress may be stated as follows:

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(1) Saving of weight.
(2) Increased safety.
(3) Increased tire life.
(4) Better riding qualities.
(5) Improved appearance.
(6) Growing scarcity of suitable wood for artillery wheels.

First-class wire wheels, owing to their construction, which not only embodies the most careful selection of materials as well as the highest grade workmanship, cost at the present time from one-third to one-half more than the best wood wheels. Starting with the inner hub, machined from a solid steel bar or a drop forging, it must be machined accurately to take the bearings as well as to be interchangeable with all five wheels, so that they may be easily detached and attached without allowing the slightest bit of play to cause squeaking or chucking, so common in most demountable rims. This feature alone was obtained by the Rudge-Whitworth Company only after several years of experimenting.

Further, having a great variety of axles in this country, to produce an inner hub capable of adapting itself to the fixed axle, as well as the full-floating type with the driving-dogs requiring at least 5" inside diameter, it was necessary to produce a hub suitable for the axles from the smallest to the largest diameter, ranging from 2¾" to 5½", and at the same time be interchangeable, as well as secure by a locking device that would permit of readily detaching as well as attaching the wheel to the hub. In common practice attaching the outer shell to the inner hub was accomplished by a fixed locking device, usually on the order of ratchets and springs. This fixed locking device did not find favor in the hands of the public because the serrations were liable to wear and dirt accumulated and springs failed.

This resulted in the Rudge-Whitworth Company giving great attention to the development and perfection of the automatic locking device, which in spite of neglect on the part of the chauffeur would not cause harm or trouble. The 1913 locking device consists of a threaded lock ring with a V-shaped groove. When the nut is slack the pressure on the groove face occurs at a point by reason of the outer shell being larger than the inner hub. Therefore, the weight of the car produces an eccentric differential creep, whereby the nut lags and so tightens itself against the hub shell. When perfectly tight the nut is concentric with the hub shell and the creep ceases. This feature might be explained more clearly by taking the opposite view of the nut on a buggy wheel, wherein a left-hand nut is fited to the left-hand side of the buggy and a right-hand nut to the right-hand side, and be more easily understood from the well-known fact of a ball or roller traveling in the reverse way to that in which the object it carries is going.

No axle which will not admit of the adaptation of this new hub construction of the Rudge-Whitworth wheel having been found, we practically have therein the only wheel which can be adapted universally to every make of car in a commercial way.

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Wire spokes were used extensively in connection with the earlier stages of automobile construction with more or less success, but this was due largely to the light weights they had to carry. As the weight of the car increased the general supposition was that the thickness of the spoke should be increased. Experience proved that this theory is entirely wrong. The Lanchester Company of Birmingham adopted a comparatively thin spoke of suitable material, giving careful thought to the bend in the spoke, so that it would leave the hub shell and rim in such a manner that it would allow for elongation without causing the nipple heads to leave the seat of the rim, or the heads of the spokes to leave the seat of the hub shell when the wheel came in contact with an obstruction. Many months of careful experimenting and road testing served to solve the problem, resulting in the Rudge-Whitworth triple-spoked wheel, which overcame the weakness consequent upon the side strains to which a wheel may be subjected in leaving a rut or crossing a car-track. Special machinery had to be invented and perfected to depress the rims, as each size of hub shell and rim required a different angle. The same may be said of the bend of the spoke leaving the hub shell. A 120-mm. hub fitted to a 36" x 4½" rim requires a different bend in the spoke, as well as a different angle from which the nipple seats in the rim, as compared with a 62-mm. shell and a 36" x 4½" rim.

We find to-day one or two advocates of substituting wire wheels on existing cars now fitted with wood wheels, the local garage men purchasing hubs, rims, spokes and assembling them to fit the job. This is bound to result in linking the hub and rim together at wrong angles, thereby causing spokes to break and loosen and the wire wheel to be brought into disrepute.

Many makers of Q. D. and demountable rims claim that their rims are suitable for wire wheels. In examining the Q.D. rims now manufactured, we find their weight far in excess of what is really required to support and carry a pneumatic tire inflated to 70 or 100 lbs. pressure. In order to reduce this weight it would be necessary to convert the solid side-rings into hollow rings. This would be very expensive and I doubt if it would be commercial.

In tests recently carried out at the Standard Roller Bearing Company's laboratories I found these solid rings blew off with the tire inflated to 180 lbs. pressure, showing that the margin of safety was none too great; whereas a Q.D. rim weighing 10 lbs. less per rim, but of suitable material and design, withstood an exactly similar test up to a tire pressure of 275 lbs. before showing the slightest yield or defect. Demountable rims as applied to wire wheels are wrong in principle and fact; first, because they require a double rim, thereby adding the weight of the second rim; second, because undoing three to nine nuts on as many bolts to effect a change of tire, is a much longer and more difficult operation than undoing one nut. With the Rudge-Whitworth detachable wheel, equipped with a Q.D. rim, all of the advantages of any demountable rim on a wood or wire wheel are obtained, in addition to a saving of about half the weight and about half the labor and time of changing. Going further into the

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subject, it might be said that the several wedges that constitute the fastening of the second rim to the fixed rim, have a tendency to release the tension on the spokes opposite the point at which the wedges are applied, thereby taking away one-third of the efficiency of the 70 spokes.

Some writers have criticized the extreme bulge of the wire wheel hub, stating that in deep ruts and in coming in contact with curbs there is a tendency to throw undue strain on the spokes, causing loosening, if not breakage. In actual experience I have not found that this affects the wire wheel to the extent of one per cent., and in my own experience in driving over both English and American roads, covering a period of several years, I have never broken a single spoke through this cause. Some engineers have advocated the narrowing of the hub flange and reducing the spread of the hub by crossing the spokes. This practice was carried out in the early stages of wheel construction abroad and found to be very inferior to the triple-spoke scheme now in general use.

By a special process of rust-proofing, wire wheels are to-day immune from rust effect on the life of a wire wheel and wire wheels have been in use for several years without the slightest deterioration from this cause. Neither heat nor cold has the disastrous effect upon wire wheels that is so common in causing wood wheels to shrink from their hub flanges, subsequently causing them to become loose and squeak, as well as to get out of true. Rarely do you find the four wheels of a wood-wheel-equipped car all true.

## DISCUSSION.

PRESIDENT MARMON.—I would like to call attention to something that happened in the last five-hundred-mile race at Indianapolis. While it is true that the race was won on wire wheels, two of the teams that entered, changed over in practice from wire wheels to wood wheels. They gave as the reason that in entering the turns at speed, which tended to make the car skid over (true at seventy-five or eighty miles an hour on the Speedway), the front wheels would buckle at the rims a sufficient amount to entirely upset the steering, by changing the pivot distance, and then suddenly drop back to original position, making it difficult to handle the car.

J. G. VINCENT.—The paper certainly gives the wire-wheel side of the story. I am in favor of the wire wheel in a general way, but there are some points that ought to be brought out on the other side of the story. The demountable feature is absolutely the biggest advantage in favor of the wire wheel. I certainly hate to take off a demountable rim from a wood wheel. The next point I think is the tire saving. On our cars I found an actual weight difference of seventy-eight pounds per car. That is, taking in one instance a car fitted with wood wheels and Firestone rims and two extra tires strapped on the back of the car, and in the other case a car equipped with wire wheels, there is a seventy-eight-pound saving on the four wheels. The extra wheels weigh about the same as the Firestone rims and tires.

Another point that must be considered is carrying the extra wire wheels. It just so happens that with the tire carrier we have adopted

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on the back of the car, we can carry two extra wheels when backed up to each other, without special arrangement. That does not often happen, especially if you are provided with very heavy wheels. It does not work out so very well where you are carrying the spares on the side of the car.

One of the first difficulties I ran into in cross-country work was to get any garage to wash my car. Going in with the wheels full of mud the washer charged me about a dollar extra.

I got into some real mud around St. Joe, Missouri, and it was my experience that the wood wheels went through more easily. My wheels sometimes balled up badly and kept so. They looked very much like brazed steel wheels with stamping inside and out. I would get down into the rut of that nice thick, gumbo mud and the wheels would spin around the edge of the ruts and not go anywhere.

I had trouble with the enamel coming off the spokes. When you get out in the mud of the western roads, the enamel is going to come off the spokes—that is all there is to it. Just how big a point that is I do not know. I put it down as one of the biggest points to overcome in the wire wheels because we cannot decrease the spread of the spokes. We should consider that in this country we use larger wheels than they use abroad, on an average. For instance, we are using 37 by 5-inch tires; that makes a pretty large sized wheel. If you decrease the spread of the spokes at all the wheels will not stand up. I have seen some wheels in which all the spokes loosened up in a thousand miles. Of course, I abused them as much as I could. At the same time I had another car on wood wheels that came through all right. That must be looked in the face.

I noticed some saving in tires. Just what that is I do not know. As far as the riding qualities are concerned one has to be smarter than I am to ride in a car and tell whether it has wire wheels. I believe nobody can tell.

F. E. Moskovics.—May I ask if Mr. Vincent had any trouble with the locking device or squeaking?

J. G. Vincent.—I had no trouble with the locking device. The automatic tightening device was almost too efficient; it tightened it up so well I had to use a heavy hammer to get the rings loose. But I would not hold this against the wire wheels, because they were rushed through in a hurry for me and the rings did not fit well.

I had some trouble with squeaking. I think I should not bring that up at all against the wire wheel.

F. E. Moskovics.—Perhaps the chief feature of comparison of the wire with the wood wheel is reduction of peripheral weight. I would like to know whether there was any difference in acceleration or working effort?

J. G. Vincent.—I will explain an acceleration test we made on one day and in as fair a manner as we could. We have a standard test in which we drive the car ten miles an hour, one man reading the stopwatch, another driving and another reading the speedometer. We read the mileage up to ten seconds, pushing the accelerator clear down, accelerating as fast as we can. We got exactly the same results in both cases.

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DAVID FERGUSSON.—We have been trying wire wheels experimentally for about eighteen months. We can find absolutely no difference in the life of tires on wire or wood wheels. The worst objection, I believe, is washing and cleaning the wheels. I understand that some of the best makes of highest-priced cars in England are going away from wire wheels to wood or pressed steel, mainly because of that washing feature.

T. B. BROWNE.—I have used wire wheels myself for the last two or three years, after using wood wheels for many years. I find that they are a great improvement in many ways, especially in tire economy. I have a Napier car now which weighs one and a half of our tons. Using 120 mm. tires on that car the average life for the tires is very nearly 5,000 miles. Before I used the wire wheels the average life of tires on similar cars was very much less than that, not more than 3,500 to 4,000 miles. I have been very much surprised to find the great improvement. In our country we use a steel-studded tire a great deal. I have not seen a single steel-studded tire since I have been here. Of course, they do not have so long a life. We find we have to use two of those tires with very big studs, on our cars in service on our asphalt roads in London.

I think the cleaning question is not a very great one. When I thought of getting the car I have now my chauffeur said "Please don't get a car with wire wheels." He ran them down in every possible way, because he had heard they took a lot of trouble in cleaning. I think you have to get a special brush for cleaning them and also learn how to clean them. I believe they now take very little longer to clean than wood wheels; they certainly do take a little more time but not a great deal. It is not a serious objection. The enamel that is on them does not seem to rust off at all. I have had this car now two years and have not had the wheels reënameled. I have run the car over all kinds of surface. I believe there is not anything in that point either.

H. C. WILSON.—May I ask if the English practice has determined any load limits on the wheels?

T. B. BROWNE.—We have nothing in the way of a fixed rule, that is a general standard.

H. C. WILSON.—Have you any for trucks?

T. B. BROWNE.—No.

F. E. MOSKOVICS.—Some suggestion has been made that the difference in acceleration between wood and wire wheels would be more marked in lighter cars; that beyond some weight simply expressed in "heavy cars" there would be probably no difference between wood and wire wheels. Have any of our guests made any tests of lighter cars?

PRESIDENT MARMON.—Mr. Pullinger, can you give us some information on that point?

T. C. PULLINGER.—No.

E. R. HALL.—We have made some tests on tire life on both wire and wood wheels, to get a direct comparison of the two under exactly similar conditions. Our results have been very surprising but we have not followed them through far enough to make any announcement. I may, however, state that the results have been quite the reverse of what we expected.

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C. T. F. BENSON.—It might interest you to know that the company I represent* have been using wire wheels. We have found that the tendency towards the artillery wheel type is growing in England. We circularized our agents this spring, asking if they could give an idea of the general tendency with their customers. Out of about one hundred and fifty agents, one hundred and forty spoke in favor of the artillery type of wheel. As a consequence of this we have decided to abandon wire wheels entirely for 1914.

The main arguments against wire wheels is the difficulty of washing and cleaning, and, in my opinion, the more important one of rusting due to water creeping in between the spokes, nipples and rim. In the artillery type of wheel you have a thick felloe through which it necessarily takes water some time to enter. On the steel wire wheel there is only the thickness of the rim, so that immediately the wire wheel gets into a puddle of water sufficiently deep to go over the rim, you have water trying to get in past spoke, nipple, security bolt and valve, which causes rust and consequently deterioration of tires and tubes.

With regard to acceleration, I cannot speak definitely, but personally I think there is nothing in it.

With regard to tire saving, the quality of tires is not sufficiently standard to speak definitely without very exhaustive trials. I know from personal experience that I can get a great difference in the mileage of two different tires on the same car.

PRESIDENT MARMON.—I would like to ask Mr. Benson whether in the 1914 artillery type of steel wheels you will retain the demountable feature common to the wire wheels?

C. T. F BENSON.—Our wheels will not be rim demountables as those in use here; they will be detachable, but not of the same form as those we have at present.

PRESIDENT MARMON.—You will change the entire wheel?

C. T. F. BENSON.—Yes.

THOMAS CLARKSON.—I would like to ask, Mr. President, whether in this corrosion or rusting of the wire wheel the method of protection by sherardizing has been used or could be applied. It is a thin coating of zinc applied at a comparatively low temperature.

I would like to ask also as to the limits of weight-carrying power of the wheels. I take it they have been applied so far to pleasure cars only. One of our prominent engineers on the other side bet me a new hat over two years ago that I would be using wire wheels on buses within a year. But as a result of the tests which have been made of the buses constructed by the Daimler Company fitted with this type of wheel, I have won the bet.

PRESIDENT MARMON.—Mr. Houk, can you say anything about the sherardizing process?

G. W. HOUK.—We are using a rust-proof process the same as used by Rudge-Whitworth in England, which has stood several years' test.

*Humber.

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C. S. MOTT.—When Mr. Vincent was talking about the weight of wheels he mentioned the weight of the artillery wheels equipped with one of the well-known demountable rims. But it so happens that those rims weigh a great deal more than some of the other well-known efficient rims. I think he mentioned that his artillery wheels weighed about seventy-odd pounds more than the wire wheels. If he had used either of two other well-known types of demountable rims, his artillery wheels would have weighed less than the wire wheels.

It is my understanding that with the wire wheels such as the English use, they use a clincher rim. In this country people have had about all they want of the regular clincher rim, having to use soft-bead tires and stretch the tires over the rims. A great many people in this country drive their own cars, and I do not for a minute believe that the American public will put up with the clincher tire they used to have. The demand will be for the quick detachable tire, with non-stretchable bead; which, of course, can only be put on a cut rim or a rim with separable flanges. If there is anything in the wire wheel, it has to be worked out in some way with either the demountable rim or some manner in which the Q. D. tires may be used.

CHARLES WHEELER.—Mr. President and gentlemen, I have a few points which I would like to submit to you. The question of rust has been raised. Personally I do not attach great importance to that. I think the reason was given by Mr. Leland in his speech the other night; it is the "knowing how," knowing how to overcome rust. With many mechanical apparatus on the other side we have got over the difficulty. You do not attain that sort of result without a good deal of investigation. If any one has had failures solely due to rust, it is simply because he has yet to learn "how."

Mr. Wilson raised the point whether wire wheels have been applied to trucks or commercial vehicles. I think I can state authoritatively that they have not been so adopted.

The question has been raised of the difficulty of cleaning wire wheels. I am rather surprised that that has been raised, because my colleagues from England, in common with myself, have not yet found a car in America that has been cleaned after it had left the factory. (Laughter.)

Your President raised a point at the opening of the discussion with reference to the five-hundred-mile race, indicating that a little enlightenment is desirable on the reason certain drivers changed their wheels at practice. That was probably due to "mere fancy" on their part. I do not blame a man for changing back to something that he has greater confidence in, that is playing to his fancy. But I would like to make this observation: the car with the changed wheels did *not* win, and the car that won had wire wheels.

F. S. BENNETT.—I have still an open mind on wire wheels. Last year I supplied probably 20 per cent. more wire-wheeled cars than this. That may be accounted for by the fact that we have this season a better form of demountable wheel; which goes to show that customers do not mind so very much which wheel they have, so long as it is easily demountable.

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Mr. Houk referred to the greater prevalency of blowouts in American tires or in tires used over here, than in England. I find exactly the same thing in England, that American tires blow out a great deal oftener than the English tires which are used in England. That, I think, is partly accounted for—I put this purely as a theory—by the fact that they have been fitted on detachable rims with the rim split so as to make it quickly demountable, and that at the place where the ring splits water has been allowed to get into the tire. The reason I mention that is because the American tires have mostly been on American rims and the English tires on English rims. I think that if you absolutely keep the water from the inside of the fabric, you will not get the blowouts, which I have no hesitation in saying are much more frequent with American tires than English.

In the figures given by Mr. Houk for the Daimler test we have fifty sets of tires of each kind. The wood wheel mileage of 2,000-odd seems to be extremely low. It should have been much more than that.

As regards acceleration of the car, I think without a doubt, because I have tried it on exactly identical cars, there is a sense of liveliness in the wire-wheeled car which you do not quite get in the wood-wheeled.

Mr. Browne referred to the life of tires with steel studs being shorter. In the Victor tire test steel-studded tires had considerably more life in every case. This was a fairly well observed test.

One of the difficulties you might meet with here is keeping the spokes from rusting, because you have a different condition than we have. Your wheels are going through mud and sand, giving a grinding effect, which will remove the enamel.

I think Mr. Houk covered practically all the good things of the wire wheel except one, that it is very much more difficult for the man who wants to steal your wheel to carry it away than a plain rim.

W. G. WALL.—Mr. President, I have been listening to the different remarks made on this subject of wire wheels. It appears to me that it is greatly a matter of design. Wood wheels we make practically all alike; that is, mostly of the artillery type quite similar in design. Wire wheels are not only spoked differently but the manner of attaching is quite different in the different designs of different makes. We can no doubt learn a great deal from the experience of our British cousins in this matter, but it appears to me that they are working under entirely different conditions from what we are, just as was brought out a few minutes ago. They have very little rough-going and deep mud to contend with; we have considerable.

Then their wood wheels are made largely of what is no doubt a much inferior stock to what we claim to make ours of. The tests that have been made showing the difference in the strength of the wire wheel and the wood wheel, as I understand, have been made mostly on wood wheels made up of wood which is much softer and also more brittle than the second-growth hickory which we use.

Mileage of tires with the wire wheel and the wood wheel the National Company have tried out to a considerable extent on the Speedway

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in Indianapolis. Practically no difference was found. In speed also practically no difference can be found. We have repeatedly taken the same car and put on a set of wood wheels and driven it a number of laps, and then, without taking it back to the factory, changed to the wire wheels right on the track, and run again with the same drivers, under the same conditions exactly. We could find absolutely no difference.

While the matter of attaching demountable wire wheels has been worked out fairly well in several designs, in others the locking arrangement is anything but ideal. I know of one prominent car breaking on the Speedway just before the last five-hundred-mile race, all four of the locking dogs at different times during practice. These locking dogs were made of steel; one would have thought they would hold, but they broke one after the other.

There are a great many conditions which prove to my mind that the wood wheel is equally as good as the wire. Of course, we are all interested in giving the public what they want. I am entirely impartial personally in the matter.

I was very much interested in what Mr. Vincent said, because I think as a rule any new thing which is being tried out to a considerable extent has many more advocates than the old type. I was very much interested to hear that the Humber Company expect to discontinue wire wheels and use steel ones. Of course, I can see advantages for the tubular metal wheel, when proper wood material cannot be had.

HENRY SOUTHER.—The matter of choice of the wood or wire wheel is not easy to make until you live with it. I am biased now, but when I went to England last winter I was open-minded in the matter. A car with detachable wire wheels of the Rudge-Whitworth type was put into my hands. I made many wheel changes, voluntarily and otherwise. I assure you I hate the thought of going back to the Q. D. or demountable rim. If there were no other good point than that, my choice would be for the detachable wire wheel. But I believe there are many other things.

To touch the thing broadly, a great many people going into the wire wheel business and experimenting with wire wheels in this country and in Europe, in England particularly, are thrashing over the mistakes already made by Rudge-Whitworth. Rudge-Whitworth started from the beginning. It cost them a great deal of money to learn what they learned; and what they learned does not stick out all over the Rudge-Whitworth wheel either. I was at their plant nearly three months and must confess that I kept right on learning nice little engineering points right up to the last day.

The matter of rust in this country is important, but it has an answer. I know of no method of preparing wire spokes or wire anything-else to go about plowing up a field with that will keep enamel or "rust-proof" or anything else on. That is not the legitimate function of any wheel. Yet we call upon some of our wheels to do it. It does not do the wood wheel any good; I venture to say the wood wheel rim looks pretty bad after getting through prairie mud of the kind that is described

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by Mr. Vincent. The answer to the rust proposition is this: An extra wheel or two are carried. It is a very easy and cheap matter to have a wheel reënameled. It does not lay the car up one minute; the extra wheel may be sent to the enamel shop, enameled and returned. There is no difficulty about it whatever.

As to the question of steering brought up by Mr. Marmon, he told me about that when I first landed in Indianapolis. I was not idle all day looking at the races and think I have gotten to the bottom of it. The bottom was expressed very well by Mr. Wheeler. It was the notion of the driver that he could not do quite as well, but he had a car which was being then developed for racing purposes. The car which had been developed kept its wire wheels and did steer.

The matter of clincher rim against Q. D. is, I believe, likely to be taken care of all right. I will not say the Q. D. is unknown in England, because it is known, but the clincher with its tire lugs or security bolts is almost in universal use. It is light and efficient. With the spare wheel the clincher may be used very much more easily than otherwise. However, an English rim brought to this country is going very well, weighing only five or six pounds more than a straight clincher; there seems to be no difficulty about it whatever.

In the matter of tire life I had the pleasure of knowing Percy Martin, manager of the English Daimler Company—I have known him for many years—and went to him and heard the story which was written by Mr. Houk in his paper. This was before he knew I had any interest whatever in wire wheels, so I believe it to be thoroughly authentic. I believe that the peculiarly short life of the studded shoe must have something to do with the particular Daimler car in use. It certainly was a long enough test to stand scientific scrutiny. It was not a minute or a week; it was many weeks. And I cannot help thinking that there must be something in the claim. This test was conducted under practical conditions.

I had a discussion with a prominent engineer this week in Detroit on the question whether a wire wheel strikes the tire as hard a blow as the wood wheel. The matter seems very clear. The wooden spoke is a direct line between the hub and the rim and is capable of striking a very stiff blow. The spokes in the under half of the wire wheel are certainly not capable of striking any blow at all; there is only the stiffness of the tire and the little support behind it of the steel rim. In England there are very few stones to create stone bruises. I suppose the stone bruise is the one serious cause of blowouts. The fabric is jammed between the stone and the rim and bruised, and water gets into and rots it, from the outside rather more than from the inside. I have seen many a shoe come off that had a very black spot on the inside of the shoe as the result of a stone bruise and subsequent rotting.

The question of detail engineering knowledge in the wire wheel takes me back to the old bicycle days. We had an epidemic once of broken spokes. I believe we had forty different kinds of wire in the testing room and in use in an attempt to get away from broken spokes. We

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never did do it by changing the wire, but a little bit of change in the bend of the spoke where it lay against the hub flange stopped it absolutely. It made no difference whether hard wire or soft wire was used. The trouble disappeared immediately when the right kind of engineering knowledge was found. It took a long time to find it.

# THE INFLUENCE OF THE SALES DEPARTMENT ON THE DESIGN OF MOTOR CARS

By F. E. Moskovics

(Member of the Society)

A few years ago the design of motor cars was practically dictated by the sales department, the engineering department being merely a way station to put the views of the sales department into such technical form as would enable the factory to manufacture a car therefrom. This was due chiefly to the embryonic condition of the industry and also to the fact that substantially all the real executives and heads of factories were themselves salesmen, as well as to the fact that there was no intelligent public demand. The motor car was new; the man in the street did not know what he wanted; horsepower varied from 4 to 120; gearboxes from belt to direct drive. Technical knowledge was as yet unmated with experience—so, naturally, the views and influence of the sales department was dominant and supreme.

Then, a few cars appeared, which due to their great mechanical advances, made a profound impression on the public. The design of these cars was actuated solely and purely by experience; the result was Renault, with light weight and shaft drive; Mercedes, with selective transmission, mechanical valves, cellular radiator, etc. Coincident with the arrival of these cars appeared the awakening of public demand, and, whereas the early engineer taught the public what it ought to have, today the public is surely telling the engineer and manufacturer what it wishes to have, in no silent voice.

About this time the influence of the sales department in the matter of design began to wane a little, in a large degree from the fact that any car on four wheels would sell. It was not so much a matter of which car was best, as what car could be delivered. Now, if we can assume that the day has passed when a customer considers himself fortunate if he can obtain an early delivery; if we take for granted the absolute necessity for stronger basic work (sound financing, good engineering, efficient production and economic and effective selling); if we can thoroughly grasp the why and wherefore of inter-department economies, and the need of inter-departmental coöperation, and, with these things in mind, grant the advantages that may be attained, we can approach the subject of this paper from a more intelligent angle.

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## PURPOSE OF PAPER

It is not the purpose to attempt to lay down rules or theories of salesmanship except insofar as they affect the relations of the sales department with the engineering department, and the influence that the sales department may bring to bear on the engineering department. In considering the subject certain definite conclusions must be assumed: What is the object of the organization as a whole? Is it to make the greatest mechanical success, regardless of financial results, or to make the greatest financial success—to pay big dividends? Taking the latter as the most logical and sought for result, obviously, that relationship of the two departments which will tend to create the greatest efficiency of each and of both as a unit is the desirable and ideal. Obviously, again, the greatest car in the world, from a mechanical standpoint, could not be marketed without a sales organization or sales channel of some sort to present it to the prospective buyer nor could the greatest selling organization under Heaven make a permanent selling success of a thoroughly poor and badly engineered car. Accepting this conclusion, then, let us approach the subject from the viewpoint that each department is dependent for sustenance and success on the other, and that each is quite useless without the other, and that the ideal condition is obtained by taking the best ideas of each and molding them to the greatest mutual advantage. If the sales department were fitted and trained to authoritatively inform the engineering department what the trend of the public demand evinced; if the engineering department were, by virtue of its confidence in the views of the sales department, in the receptive frame of mind essential to the acceptance of these views; and if the blended opinion of these two departments fitted in with the production standard that their particular organization was best fitted to handle, would not this nearly approach the ideal?

## COÖPERATION

In many organizations the sales department wears a halo unwarranted by facts, and bad in principle. This is due to many causes, the main one being that it actually brings in the dollars; it is apparently the department that creates the much sought dividends. Besides it is the department that comes into contact and mixes with the outside world to the greatest extent. It is, or should be, better fitted to tell of its own importance and greatness than any other arm of the business; its business is the art of selling, and it can, or should be able to, sell itself as well as it praises and sells the product at its disposal. In other words, the sales department is the mouthpiece of the organization, the real point of contact between that final judge, the ultimate consumer, and the factory. Naturally, this condition ofttimes becomes galling, especially to one so little given to the study of environment as the average motor car engineer. The result is lack of regard for the ideas, views and opinions of one department for the other. Of course, no lasting benefit can come from such a relationship. Each department has its functions; each is all-important to the success of the other. Healthy and deep respect for each

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other's views in everything that pertains to the welfare of the organization as a whole is requisite to permanent success.

In the past the average sales department has had little real knowledge of the art of motor car building; what it gleaned was of a purely superficial and perfunctory character, usually limited to parrot-like repetition of a few technical platitudes called for want of a better name "talking points." No systematic attempt was made to thoroughly ground the salesman in the rudiments of the profession, nor did he, for lack of initiative and time, obtain the information on his own account. How few salesmen of even today have a real general knowledge of the basic facts of the business. They have been, and to some extent are still chosen for their appearance, glibness of tongue, and personality, rather than with due regard to the adaptability to learn, digest and transmit knowledge in a clean-cut manner.

The day is, however, rapidly approaching, if indeed it is not already upon us, when motor cars must be *sold* and not bought. The buying public become car-wise and knowing what it wants, has little respect for or patience with the man who cannot explain in a clear, concise and logical manner the different points of a car that may come up for discussion. The man buying his second or third car has well-defined ideas of his own, and cannot be talked into an unwise investment, nor influenced by mere talking points. The points must be real points, and be well presented. The public craves information in a rational form. The time has passed when anything less will do. This is a day of facts, not fancies. The merely magnetic talker has seen his day.

As illustrating the kind of salesman who cannot succeed today, the following story of a few years ago will perhaps suffice: Jones, the star salesman of a prominent foreign car, was asked by a prospective buyer what form of ignition was used on his car? "Low-tension make-and-break," he responded. "What is the difference between low-tension make-and-break and high tension?" the customer inquired. Jones was momentarily nonplussed (here was a point that his motoring education had not covered), but only for an instant. "Are you an electrical engineer?" he asked. "No, I can't say that I am," Mr. Buyer replied. "Then, really it would be quite useless for me to attempt to explain it to you," said Jones. When Jones told me the story to show how clever he was, I asked him what he would have said if the prospect had said that he *was* an electrical engineer. "Why," said Jones, "I would have told him, 'Then you ought to know more about it than I do.'"

The day of Jones is coming to an end. Naturally, an engineer, who has been brought up on facts, whose entire make-up should be to take nothing for granted, who wants reason (even to an unreasonable degree) for each change of design or model, whose education and training from the university to the factory has been to accept only laws—not fallacies—is not readily impressed by the desire or opinions of sales departments of the type indicated. He feels immediately, and often correctly, that demands born of such scant knowledge are mere shams to cover up its own weakness and an attempt to shunt to his shoulders a

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responsibility which his own commercial instincts have not, except in a few rare instances, been developed to bear. If, however, backed up by the chief executive he carries his views and ideas, to the exclusion of the other department, he assumes an enormous responsibility, and only discord can result. If, to support his position, he cites his own experience and quotes from the statements of the few users of his product with whom he has come in personal contact, he is treading on very thin ice indeed. Right here is the pitfall that lures many engineers. They accept too blindly the result of a few experiments or the words of a few persons. What is needed to intelligently guide them is enormous road experience and a knowledge of the demands of hundreds of people. In other words, the average engineer is too provincial and self-satisfied with his work to be in a position to judge what is the desirable and correct design of the future. Is it then any wonder that we see so many cars whose appearance is far below standard?

The blame for this condition should, however, not be charged to the engineer so much as to the executive, who usually loads the engineer down with a mass of work not rightfully within his province. How many engineers are doing the work of chief inspectors, assisting in the purchasing, service and production departments? Few factories provide the engineering department with adequate help of caliber capable of handling properly the detail which the chief engineer feels must be watched by his department, the result, of course, being that the head of the engineering department, while thoroughly familiar with his own product and knowing in a general way the trend of the industry, simply has not the time to follow those niceties and refinements of design and beauty of detail in small things, which the foreign engineer is teaching us, and which are molding public opinion so strongly.

### A PROPOSED SOLUTION

Could the engineer have at his disposal the concrete views of a trained body of men; could these views be presented to him in time to reasonably allow him to get up new designs; could he be placed automatically in closer contact with the user of his car, is it not evident at a glance that enormous benefits and economies would result? It is clear that the economies so necessary to success in the industry today will not allow an organization to have a specially trained corps of men for this work. Where then should the engineering department get its closer contact with the public? Analysis points plainly to the fact that it is through the sales department. Moreover, the bringing of these departments into closer working relation should serve to raise the sales department to a higher standard of knowledge of its own products as well as of those of its competitors, thus enabling it to become more efficient in its own field and more capable of placing intelligently before the engineering department its views of future necessities of design, including comparison of the products of the particular organization and of competitors in actual service. In addition the sales department should grasp more understandingly the large problems of the production department, deterring it from making sug-

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gestions which on their face are out of accord with the policies or possibilities of the organization.

### ADVANTAGES OF CLOSER CONTACT BETWEEN THE TWO DEPARTMENTS

Granted that an engineer has a clear-minded and well-trained sales organization to present his car to the public, one that he knows has a very good rudimentary knowledge of the profession, has he not, when it comes to forecasting the demand of the future, an enormous advantage over his brother, who is in constant discord and conflict with his sales department? Generally speaking, the design of a particular car is based on the theory and reason of the engineer. If he cannot impress those nearest to him with the correctness of his theory or the soundness of his reasoning, there must be fallacy somewhere in the organization. If the views of the sales department be subordinated, the chief executive will receive continually communications giving the best excuses in the world why the product is not selling. If it be the engineering department, either a twelfth-hour change is necessary, or, if the matter has been brought up in time, the engineer will be compelled to lay out something against his will and judgment. If, on the other hand, the points of contact between the two departments were such that during the period of inception of the car, the engineer were kept constantly advised of the views and ideas of the sales department, of the success of his product in the hands of the public, would not the resultant product be very much better? Would it not be easier for the sales department to market such a product enthusiastically? Would not the engineer be given confidence that he was building something that the public demanded, and that he was filling a long-felt want? Would not the sales department assist greatly the technical work of the engineer?

Summed up, the problem has two aspects:

First—In the majority of instances there are entirely insufficient points of contact between the sales department and the engineering department.

Second.—There are insufficient points of contact between the engineering department and the ultimate user of its product.

How, then, to cure these apparent defects? Surely, an annual meeting where all the salesmen are brought together in a joy-feast is not the place; the chief engineer, let us say, addresses the body; as a whole, the members are known to be gathered merely for the purpose of mutual admiration. The average house organ is not the medium, because truths are not told there; the house organ is usually a means of self-praise rather than self-analysis.

In this paper no consideration is given to the chief executive or the general manager as a factor for the reason that its object is to suggest an automatic means of communication of thoughts and ideas between the two arms of the business, and naturally the supposed superior knowledge of the head of the organization will be superimposed on the hoped-for result of the closer union of these two departments. As there appears

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to be at present no definite channel through which the two departments can come more closely together, the writer suggests:

First.—A weekly engineering bulletin, edited by the chief engineer, taking up in groups the different parts of the vehicle, preferably employing the same nomenclature the factory has given to the various parts; appending the part or piece numbers in question (this will familiarize the salesman with part numbers).

Pains should be taken that the bulletin be free from abstruse technical terms and data which might not be easily digested. Care should be taken to inquire whether the salesmen can read simple blueprints; if so, diagrams explaining the theory of the various points should be furnished. The salesman would thus obtain a direct knowledge of the product which he could gain in no other way. In each bulletin a personal appeal should be made to the salesman that he request any information on any point that he does not understand thoroughly, and a further explanation should be cheerfully and gladly given to him. The chief of his department should constantly urge him to correspond directly with the chief engineer on these points, and it should be strongly impressed on his mind that it is no disgrace to come back and say that he does not understand the topic discussed in a certain bulletin. In fact, the writer would urge that upon publication of the bulletin it become mandatory on the part of the salesman to express weekly his view on the topic described.

Although it is argued that the chief engineer be the editor of the bulletin, it is, of course, not necessary that he do the actual work in connection with it. He can lay out topics to be covered, and have his assistant or any other capable person collaborate with him. It is, however, the business of the engineer, to see that the bulletin actually reflects his views and ideas, the object being that the spirit of the organization be built around the chief engineer's conception and theory of the product. He need never be at a loss for a topic. If in say twenty weeks he has covered the general points of design, he may then deal with such subjects as economy of fuel, the best means of caring for the clutch, the motor starter, etc. The accessory firms alone could furnish enough data to keep such a bulletin alive for a very long time.

Is it not patent that a sales organization understanding thoroughly the car in the manner which the bulletin indicated would bring about, would be of great assistance to the engineering department, and that its value to the general organization would be increased enormously not only by reason of the efficiency of the salesmen, but because of its role as the eye of the organization?

Would not the engineer, when the time came to consider the views of the sales department, feel greater confidence in the ideas and opinions of an organization which he had reason to believe had at least a thorough knowledge of his product, than under the existing conditions? Few companies are so strongly entrenched that they can disregard arbitrarily the demands of such a sales department. Certain firms assume the attitude that a given mechanical theory is correct simply because they have adopted it, but even they, if they are far-seeing, know the day is coming when a just retribution may overtake them.

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The sales department should have a voice and influence in the design of the car, but must first be so schooled and trained that it will harmonize with the organization rather than be a discordant note.

The advertised accessory is perhaps the most prolific source of annoyance and discord between the average engineering and sales departments. The inflated demand sometimes created by artful advertising, tends naturally, to make its first impression on the mind of the sales department. Many very good accessories have failed of adoption from the fact that the ridiculous claims made in advertising did not appeal strongly to the always analytical engineer. On the other hand, it must be considered that no thoroughly bad article can support a sustained advertising campaign; it must have real merit or it will not survive. If the sales department is able, through advance knowledge it receives from the engineering department, to controvert intelligently arguments which prospective customers put to it, is it not reasonable to suppose that it will not bother the engineering department with quite so many suggestions for the adoption of new accessories or articles of equipment? Also, when it makes a suggestion, would not the chief engineer have more confidence that the article presented is worthy of his consideration?

With regard to my second suggestion, contact between the engineer and the owner, the problem is somewhat more simple. The appended form could be sent to every agent and distributor of the factory, with positive instructions that it must be filled out every sixty days. This would give the engineer first-hand information as to exactly how the product is being received. It would enable him to eliminate apparent defects due to local conditions. Let us assume that from the replies it becomes evident that there is considerable noise in the shifting of gears. It is not supposed that the average agent will be able to analyze the clutch problem, that he can tell whether the clutch is too heavy or the gear ratios incorrect. That, of course, remains for the engineer to diagnose. But the replies will place in your hands, without delay, troubles resultant upon design or manufacturing defects. Again, let us assume that the gasoline and oil consumption are very high, much higher than you know should be the case; the service department will instantly get into communication with the dealer and help him to alleviate the condition.

Of course, the theories advanced here, like all theories, are useless, if not used. The object of this article is to point out a means whereby the influence of the sales department on the engineering department can be brought to a stage of intelligent coöperation.

## FORM

FOR THE CONFIDENTIAL USE OF THE ENGINEERING DEPARTMENT

It is highly important for your own benefit as well as ours that you give us the following information as accurately as possible. It is our endeavor to make our cars meet the severest general requirements and only by a definite, direct and accurate knowledge of how they act under

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widely varying conditions can we hope to accomplish this. Please be guided accordingly.

Date:
Agent's name:
Territory covered:
How many of our cars are in operation in your territory?
What is mean altitude of territory covered by you?
What is general topography of territory covered by you? { Mountainous / Hilly / Level }
Are road conditions good?
If not, please briefly state conditions and about what proportion of roads are macadamized, etc.
What is maximum average temperature?
What is minimum average temperature?

1. Does our line have power enough for your customers. If not, what would you suggest?
2. Is our motor quiet enough for your clientele?
3. Is our line flexible enough?
4. Do our motors accelerate rapidly enough?
5. How do we compare with competitors in our class? Please state which competitors, if any, surpass us?
6. Is the fuel consumption (both oil and gasoline) satisfactory? Please state your experience generally.
7. Are our gears quiet enough for your clients? If not, please state which are noisy.
8. Is the clutch action satisfactory, both as to engagement and holding?
9. Does our spring suspension meet with general approval?
10. Is our steering gear meeting all requirements?
11. Are our gear ratios correct for your territory?
12. Have you heard any criticism of our upholstery, either in material or workmanship?
13. Have you heard any complaint on the accessories we use? If so, please particularize.
14. Have you had any trouble reported on the bearings we use?
15. Is our rear axle construction meeting the requirements of your trade?
16. Please state any general criticism on appearance or general design you may have encountered.

This information is so important to us that we urge it be made out under the direct supervision of and be signed by the head of your organization. It will materially help us to build better cars.

## DISCUSSION.

PRESIDENT MARMON.—I think the average engineer is somewhat apt to design a car that he himself would like to drive around his own town, rather than consider the conditions of other places.

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F. S. BENNETT.—Gentlemen, as an engineer who has drifted into the purely commercial side of the motor trade, I have all along advocated a closer and keener coöperation between the engineering side and the sales side. It is very common in certain factories to find antagonism. The sales organization's suggestions are not always received by the engineering side with the careful consideration they should be. This is being gradually got over; a better understanding is now being brought about. After all, the man on the floor in the salesroom is the connecting-link between the factory and the buying public. He converses with and teaches the owner. The man who buys a car has probably talked with a great many salesmen before settling on a car. In that way he gets knowledge of the trend of design. Thus the salesman, as an intermediary between the buying public and the engineering department, has very great influence on the future of the automobile. If the engineering department will take an interest in the sales department they will be able to learn in advance what is likely to be required for two or three years.

J. G. VINCENT.—I have always managed to get along with the sales department pretty well. I spent ten years as an engineer in the adding machine business, and had to get all my ideas, practically, from the sales department. I think that the engineer will not have ordinarily any trouble in getting along with the sales department if he is open-minded and really looking for the truth. I stick to the sales department as closely as I can, getting around the country and talking with the dealers. I am always careful to investigate carefully any kicks that they get. Of course, we cannot allow ourselves to be swayed too far one way or the other by the sales department, because if we should we would probably be changing two or three times a year, instead of once a year. I think it is up to the engineer to take the suggestions and criticisms advanced by the salesmen throughout the organization and analyze them carefully in an absolutely frank and open manner.

T. C. PULLINGER.—Mr. Chairman and gentlemen, I have had little troubles in this respect, the same as you all have, and am convinced that human nature is the same today as it was a hundred years ago; familiarity breeds contempt. You are never going to get two departments of the same factory to be ruled one by the other. Our friend here says that the engineering department cannot let the sales department govern them too much; otherwise you would change models every five or six months. We have been trying in the British Isles a method for bringing the engineering and sales departments together. We get dealers and agents to meet at the works once a year, far enough ahead that the models for the coming season shall have time to evolve. Some three months prior a few of our biggest dealers come up and give ideas as to what they think will be the type of car in great requirement for the following year. We then make some models and present them at the above-mentioned second meeting. The agents are enabled to criticize not only the models we have prepared for the coming year but also to tell us the faults and failings we have had in the past. We find that exerts a great influence over the engineering department.

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GEORGE W. DUNHAM.—We have found, very unpleasantly at times, that the public have a very decided opinion as to what they want, and a great many times insist upon getting it. It is the policy of the Chalmers Company, therefore, to keep in unusually close touch with the public, and unless the demand is for some particular feature which is detrimental to the car, build our models to conform with the demand of the buyers.

In order to keep closely in touch with the buying public we are in continual communication with our dealers, district sales managers, traveling men, etc., who are spread over the field, and in a good position to know the feeling in their particular territory. Except for a few owners, with whom different members of the company correspond personally, it is through our selling and service organizations that we keep in touch with the automobile buyers and our owners, and from them ascertain what their preferences are for the future motor car. Getting expressions from dealers and representatives in the field, would at first sight seem simple, but in reality it is rather difficult to get these men to give repeatedly their ideas with suggestions and criticisms. Almost any one will make one or two suggestions, but what we want is quantities, and no opportunity is lost to express appreciation of any information of this sort. This has resulted in the past in the receipt of many letters containing suggestions and criticisms in regard to our cars, but the difficulty has been that almost invariably a man with an idea would write a seven or eight-page letter telling the history of some automobile trip that he or some friend had taken, explaining where they had gone, where they had stopped, certain hills perhaps that they had taken on high gear. After reading several pages of descriptive matter in which we were not especially interested, we would finally locate the idea, usually on the next to the last page, in a few words. Usually the letters were written in longhand none too legible. Of course, it is nice to know that the writer is an enthusiast, and enjoying the car, but what we are after in this particular case is ideas. Therefore, to get the thing into some tangible form, whereby we can get more ideas and eliminate the writing of long letters, we have issued a printed form bound in pads. These are printed on yellow paper, so as to be conspicuous, and are five by seven inches in size, so as to fit an index file. At the top of this sheet is printed, in the right hand corner:

SUGGESTIONS

KEEP THIS PAD HANDY and wherever you have an idea for the improvement of Chalmers cars—don't wait, but write it down, one idea to a sheet, and enclose it in the first envelope coming to the factory.

There is also a place for the date, city and signature, with several blank lines for the suggestion. We send these pads to our dealers with the request that they be kept in a convenient place, impressing upon them that we want their ideas and that we would be glad to have them write them out in a few words in lead pencil, and that if they do this, merely enclosing the sheet in an envelope coming to the factory, it will auto-

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matically reach the engineering department. This resulted in a large increase of suggestions and criticisms in a form that takes but a moment to read. Further, the blanks have a space in one corner for filing notations. It is obvious, therefore, that by first getting a lot of good ideas from people actually selling and using the car, and second, having these ideas so filed as to be available under different subjects, when any part of the car is being gone over from the designing standpoint, the information available is invaluable. Again, this situation puts the engineering department in closer touch than ever before with the selling force in the field, with the result that the latter are proportionately better posted on the car.

We have gone a bit further, too. We realize that in any large manufacturing institution certain variations in material or in some shop method are bound to occur from time to time, in spite of every precaution possible. We do not believe that any one can positively prevent variations creeping in sometimes, but if difficulties do occur there is no excuse for not getting after and overcoming them the minute they become known. If any trouble is occurring, no matter how slight, the more quickly we know of it the better. To get this information quickly, we arrange to receive daily reports from ten of our biggest dealers, as to just what cars are in their repair shops each day, and what work is being done on them. It may seem that a lot of work and considerable time is taken to go over these reports, but they are made out in concise form so that the information is available at a glance. If any troubles are prevalent, they are bound to show up in such a quantity of cars as are taken by the ten largest dealers; by watching their reports any repetition of a trouble is at once noticeable, resulting, possibly, in a few telegraphic inquiries and then prompt action to stop any continuation of a difficulty.

The main difficulty with the two schemes outlined above is to keep them in constant operation. This we accomplish by writing letters to the delinquents promptly. Thus we have actually accomplished what we have all thought of more or less, but looked upon as impractical. We are actually getting quantities of suggestions and criticisms and know of any trouble which may arise, almost as quickly as it develops. I believe there are not very many Chalmers salesmen who are not actually acquainted with the working of the parts of the car, knowing their functions, and having a general idea of the construction. When we are bringing out a new model we feel that we know what is wanted, and due to close contact with the sales department, by the time the car is to be marketed, our salesmen and dealers are thoroughly posted.

F. E. Moskovics.—The method Mr. Dunham uses to keep in touch with the trend of demand for design, is not quite clear to me.

George W. Dunham.—Only a few months ago I sent out a circular letter to our dealers asking questions as to what they thought the future was going to be, not that I actually thought we could work along this line, but that we wanted their opinion. We have dealers' conventions yearly, and talk over our future policy, forming advance ideas.

Another thing we have done has proven itself, I think, to be the best

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and most useful of all. We hold a Mechanics' Convention. After you build a car that will sell, you have to keep it sold. The best car in the world will prove unsatisfactory sometimes, if the people representing you do not understand the car. The selling end are posted and trained along the line of selling our particular make of car; the salesman does everything he can to sell the cars and keep every one feeling that it is the only car, of course. There are men in the dealers' organization other than salesmen, who can do the car the most good viz., the mechanics. The salesman does not understand the car except in a general way; the man who does understand it is the mechanic; to him the average owner looks as knowing all about it, and is much influenced by what he says and thinks. A little over a year ago we held a mechanics' convention. We intend to hold another this fall. The men are brought in in small groups. We cannot handle a large number to the best advantage. Last year each group came into the factory for three days. A specific program was carried out in each case. There were meetings at which stripped and torn down chassis were gone over and explained piece by piece. In our meetings the mechanics did most of the talking, giving ideas and suggestions. Then time was spent both in the factory and in going through our methods of inspection, with the result that when they went away they knew how we do things and why, and were familiar with all parts of the car, a condition which could not exist under other circumstances, inasmuch as hardly one of them would himself have had an opportunity to tear an entire car down, make the adjustments, etc. Some of them when they came to Detroit knew little about our car and methods. Before leaving they had been through the plant in a thorough manner and been thoroughly introduced to the car.

F. P. NEHRBAS.—We recently called our dealers and superintendents in, just as Mr. Dunham has outlined, and it worked wonders. The different opinions these men have given since they have seen the factory and been taught how to do certain things that they had to do, and were all doing wrong, are surprising. One point was very interesting, the difference of opinion the men coming from Denver and from Boston had as to adjusting carbureters; no two opinions were alike and no two men had the same object in view, it seemed. One looked for an even explosion; another for the greatest mileage; others were just tinkering because there was a place to screw. Now all of them work together and have the same views.

Mr. Moskovics' paper touches only a small part of the trouble. All the manufacturing departments, as time goes on, must get together more closely. In the early days the designer could put out a car and the public could take it or leave it, but now competition is getting to a point where we must listen to the purchaser. The salesman on the floor certainly does a lot of educational work with the purchaser. We should educate him from the factory and the engineering end. Then we will have less trouble with the purchaser.

F. E. MOSKOVICS.—There are two more points I would like to emphasize. Mr. Dunham brought out the fact that the salesmen knew nothing

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of the car practically, except that a certain type of motor is used and so on. The first conception of a car is had in the engineer's brain. The method of selling the car may be nothing more than the presentation of his view in a logical manner. If the departments will get together so that the sales department will not only understand the car mechanically but the reasons and the theory of it, as conceived by the engineer, I believe that they can certainly present the car in a better manner. The sales department lacks training today. It is the duty of the engineering department to train it. When the salesmen have a greater knowledge they will not make foolish suggestions; their suggestions will be more reasonable, more logical.

# Heat Treatment of Leaf Springs

By E. F. Lake

(Member of the Society)

Up to the present time the heat treatment of leaf springs has received very little attention from the automobile engineers and metallurgists. If such moving and wearing parts as the gears, crankshafts, connecting-rods, steering knuckles, etc., were hardened and tempered in the same crude, unmechanical and non-scientific manner, the automobile would never have reached the successful position it occupies to-day. While it is true that many of the new grade alloy steels have been made into springs for commercial use, they give but little better service than carbon steel springs. This is due almost entirely to the wide variation allowed in the hardening and drawing temperatures of the same lot of spring leaves. In fact, here accuracy in heat treatment is almost unknown. Yet heat treatment is what makes the transmission and differential gears give such good service in such small units. Carbon steel springs accurately heat treated often show better results in the various tests than the average commercial spring made from alloy steel. Sample springs have been exhibited that withstand some wonderful tests when made from the alloy steels, but these are wonderful only because of the poor quality of the commercial product. No such wonderful results are shown in sample gears, because the commercial product is uniformly and accurately heat treated, and the samples cannot be made much better than the daily output. When they are properly heat treated the strengths, wearing qualities and especially the resistance to stresses are so much greater in the alloy than in the carbon steels that springs made from the former should be much lighter, i.e., have fewer leaves or thinner plates. Yet such is seldom the case, rarely enough to be called an exception. When not properly hardened and tempered the alloy steels are but little better than the carbon steels as they are very susceptible to heat treatment, which must be done accurately and uniformly if strength and longevity are to be developed. The last statement also applies to the carbon steels, but not to as great a degree.

Much data and many useful formulæ have been brought forth for designing automobile springs, but these cannot be used to advantage unless

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the spring plates have been correctly hardened and tempered. One writer gives 96,000 pounds per square inch as the factor to use for the elastic limit of carbon spring steel and then compiles a set of tables that uses but 50 per cent. of this, in order to allow a factor of safety for what he terms the jounce load. This brings the elastic limit down to figures that can be obtained on thoroughly annealed carbon spring steels, i.e., those with a carbon content of from 0.80 to 1.00 per cent. The 96,000 pounds makes considerable of an allowance for a factor safety on such a steel, when it is correctly heat treated, as then the elastic limit should be 150,000 pounds per square inch. On top of this, however, but one-half of the 96,000 pounds is used to allow another factor of safety for the so-called jounce load. Springs made by the crude hand methods that have formerly been used, doubtless require this double factor of safety in design, as accuracy in heat treatment is impossible and thus a uniform temper is not obtainable in two plates of the same spring or even in two places on the same plate.

### VARIATION IN TESTS

In numerous cold bend tests of spring plates that were made for springs on high-priced automobiles I have had the breakage occur on one end of the plate when it was bent 15 and 20 degrees around a 2-inch pin, while the other end would bend from 85 to 90 degrees without a breakage. This has occurred in springs made in both Europe and America by firms of a high reputation for quality. Likewise, in tensile tests the elastic limit has varied from 85,000 to 155,000 pounds in different parts of the same plate and in different plates in the same spring. Fatigue tests have shown even greater variation than these, as the highest figure obtained has frequently been from six to ten times that of the lowest figure and in a few cases even more. The last-named is really the important test for springs, as it shows their length of life, or resistance to alternating stresses.

### HEAT TREATMENT

Spring steels in the softest annealed state have considerable of an elastic limit and will spring back if not strained beyond this. Thus it is possible to pile enough plates of this material on top of one another to make a spring that will carry any given load. This fact has saved many a designer from utter failure when the heat treatment was poorly done. Lightness of parts, however, has been the greatest factor in the success of the automobile. To get the lightest spring that will carry a given load it is necessary to put the steel in a condition that will give the greatest resiliency and longevity of which the metal is capable. This can only be done by hardening and tempering the spring plates at accurate predetermined temperatures. Automobiles travel over rough roads at from three to ten times the speed of horse-drawn vehicles and consequently put much more severe and frequent strains on the springs. Nearly all of these springs, however, are made by the same crude hand methods that were employed for the manufacture of carriage and wagon springs, which were made in anything but a scientific and mechanical manner. The usual method employed, as far as the heat treatment is concerned, is to have a

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spring fitter and his helper work at a furnace in which the temperature is supposed to be kept at 1,800° F. Into this the spring plates or leaves are laid until they absorb the temperature of the furnace. Each plate in succession is then taken out and by the use of pincers the two men make it conform to the shape of the next larger leaf. The spring leaf is next put back in the furnace to heat it to the hardening temperature and is then quenched in oil. After this it is again put in the furnace until the oil flashes or burns off; this is called tempering.

The correct hardening temperature for most of the spring steels is about 1,500° F., although some of the alloys require as high as 1,650°. With the furnaces running at a temperature of 1,800° it is a physical impossibility for the men to heat all the plates in a day's work to this 1,500° unless the work is done so slowly as to make it unprofitable. Even then the difference in the light in the shop, caused by clear sunshine and a sun obscured by dark clouds, will alter the man's judgment of this temperature more than 100°, as it must be judged by the eye. Furthermore, most spring plates are tapered at the ends and the thin ends will absorb the heat faster than the central portion and these will have different temperatures when the plates are quenched in oil. Pyrometer systems have been installed, but with this method of hardening they are only talking points, or advertising features, as the pyrometer gives the temperature of the furnace and not that of the steel inserted in it for hardening. In many cases the pyrometers are not calibrated or tested for months at a time and often the readings are 200 or 300 degrees from the correct one.

The hotter the spring plates are made the easier it is to pinch them to shape by the hand method and as the spring fitter and helper work on the piece-work system it is a great temptation to raise the heat in the furnace. Thus the 1,800° often becomes 2,000° or 2,200° and even more. This makes it still more difficult for the hardening temperature, 1,500°, to be properly judged. I have many times seen cast iron tubes with the end placed in the furnace to protect the thermo-couple of the pyrometer, melted off. Sometimes the spring plates are taken from the furnace, pinched to shape and quenched in oil without ever returning them for the hardening heat.

Many other things might be brought forward to show the impossibility of obtaining accuracy in the hardening temperatures by this method. The facts are, however, that a variation of 300° occurs in the hardening temperature of the spring plates quenched in a day's run in the best regulated shops. Any kind of a test that is applicable will show such a variation in the strength, resistance to strains or longevity of the steel as to make it a misnomer to call such springs heat treated.

To those who understand heat treatment methods it sound much like a huge joke to be told that the temper is drawn by putting the quenched-in-oil spring plates back into the furnace to burn the oil off. The oils that are used for quenching have a flash point of from 400 to 600° F. which in conjunction with a furnace heated to 1,800°, makes it impossible to keep within 100 degrees of the desired drawing temperature. For the different kinds of spring steels the drawing temperature ranges between

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700° and 900°. The correct temperature for drawing a given steel should be obtained and a variation of more than 10 degrees from this point not be allowed. With the materials and apparatus now obtainable spring plates can be tempered all day, and every day, with a smaller variation than this. It can also be done more quickly and cheaply than by the old hand methods.

A very decided change takes place in the strength, toughness and longevity of spring plates with each change in the temperature at which they are hardened and drawn. This is why it is necessary to heat treat them with no variation from the temperature which gives the best results. As steels are quite brittle in their hardest state a part of the hardness is drawn out to increase the toughness and prevent breakage in such parts as springs. In the hard state the steels have their greatest elastic limit and some of this must be sacrificed to acquire the toughness needed for the proper resiliency of the spring. Every rise of 100° F. in the drawing temperature lowers the elastic limit by something like 20,000 pounds per square inch, in the case of ordinary carbon steels and more than this in the case of alloys. Therefore, to carry the drawing temperature beyond the point where the desired toughness is obtained, weakens the spring in exact proportion to the number of degrees the temperature is raised This means putting just that much more steel into the spring to prevent i from settling under its load. On the other hand, if the drawing temperature is below the point where the desired toughness is obtained, breakage of the spring is liable to occur from too much brittleness or loss of resiliency.

Exact hardening temperatures are even of more importance than the drawing temperatures. Spring steels will not harden unless they are heated to a few degrees above the transformation point and then cooled suddenly. From 25 to 40 degrees above this point is usually allowed for the loss or lag when quenching. Tests of leaves from stock springs have shown that many of them were quenched at too low a temperature, were too soft to have proper resiliency and settled when on the car.

When hardening spring plates, heating to temperatures too far above the transformation point, has probably been the cause of more trouble than any other one thing. This is easily and often done when the furnace temperature is several hundred degrees higher than the correct hardening temperature and such is usually the case. At the transformation point a new grain structure is born, the finest that can be produced in the metal. The steel is in its densest and strongest condition. Each degree that the temperature of the steel is raised above this point adds to the coarseness of the grain; when the temperature is raised high enough the grains crystallize and distinct cleavages occur between them. Thus strength and resistance to strains are gradually reduced with each rise in temperature above the correct one for hardening.

Fatigue tests have shown that the number of alternating vibrations which a spring leaf will withstand before breaking was reduced 20 per cent. by having the hardening temperature 50 degrees too high. This means that when placed on a car the spring would last only four-fifths as long as one correctly hardened. With the hardening temperature 100 degrees too high, the number of vibrations was reduced 33 per cent. or

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one-third of the spring's life was sacrificed 150 degrees, 45 per cent. The elastic limit of the steel also is reduced in similar proportions.

With the old hand method of manufacturing such springs, as indicated above, are being continually turned out and put on cars, and no better work can be expected. The man does not exist who can quench plates all day and keep them all within 100 degrees of the correct hardening temperature. I have seen the elastic limit in different parts of the same spring vary from 85,000 to 145,000 pounds per square inch.

Crystallization is often found in spring plates. This cannot occu except from the heat treatment that the steel received. The statement has often been made that crystallization is produced by rapidly bending the steel back and forth; or, in other words, submitting it to the alternating vibrational strains which a spring receives in service. No such change ever takes place, however, as the grain is enlarged or coarsened before crystallization takes place, and this is caused only by overheating. Thus, if crystallization is found at the break in a spring plate, no other excuse can be given; it was heated to too high a temperature, either when hardening or when bending the eye or rolling the tapered ends. The first sign of weakness from vibrational strains is the starting of one crystal to slide past another, with absolutely no increase in the size of the crystals or grain. This continues until a slip plane is established clear across the piece and breakage occurs.

If leaf springs had been investigated as thoroughly as other parts of the car and as much scientific and mechanical knowledge had been applied to their manufacture, breakage and settling of the springs would have been exceedingly rare. They would outlive the car. By forming the spring plates in a machine, instead of by hand, they can be bent to shape without overheating them to the 1,800 or more degrees as is now the custom. A temperature around the transformation point is all that is necessary as the machine is stronger than men's arms. They can then be taken to hardening and tempering furnaces that maintain the correct temperatures for this work and left in these until they absorb the temperature of the furnaces when they can be quenched or cooled with an assurance that the steel will not be overheated, crystallized and weakened.

Pyrometers can then be used successfully to measure the heat, provided they are tested every day, as the temperature of the furnace will be that which is required in the steel. This accuracy will enable the designer to make the springs lighter, and it can be obtained with less cost than by the old hand method. Some might think that this would revolutionize the manufacture of leaf springs, but it is only a change that is based on mechanical horse-sense and should have been brought about long ago.

## DISCUSSION

CHARLES A. CHEVRAUX.—Mr. Chairman and gentlemen, the paper submitted by Mr. Lake is well worded. The question of leaf springs and suspension is something that the gentlemen present will admit has in the past few years been very much neglected. In the past the majority of

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automobiles were built first and suspended afterwards. The springs had to be made to fit the space left, regardless of suitability as to proper proportions. I venture to state that in the early years of the automobile industry poor spring suspension put more makers of cars out of business than anything else except perhaps motive power. After the car once leaves the factory the springs are under stress until the car goes to the scrap heap. With the exception of tires, the springs are the only part of the car always under strain.

Mr. Lake mentions that a number of spring manufacturers are not working to very close scales. In our factory we have a complete system of pyrometers in both plants. We also have a checking pyrometer installed between each pair of furnaces, so that the fitters can check the furnaces and in turn the pyrometer man who is stationed in a room by himself and the department foreman check the men who are doing the heat treating. In our method of heat treatment we allow a variation of only a few degrees of heat. We work three different furnaces at different degrees of heat; first the fabricating, second the tempering and third the drawing.

We have also done some very extensive research work in drawing with a liquid bath. In fact we have adopted this method on part of our work and are figuring on using it exclusively. There is mention in the paper as to drawing all the plates of one particular spring at the same temperature. In time practically all manufacturers of high-grade springs will adopt this method. We place the entire spring assembly into the bath at one time. Our pyrometers are checked daily. Mr. Lake refers to a variation of ten degrees in drawing temperature. With the chemical bath we use the temperature can be maintained within this limit.

Machine fitted springs have been experimented with for years. You can find all kinds of patents on fitting machines for leaf springs. I am sorry to state that a great many of them have proved more or less failures. A great many have been used; in fact they are used today in the carriage spring line. Very few machines are being used in automobile spring production. According to a new method, the plates will come out of the fire, be placed in a machine and travel through the oil. This machine will be practically a combination of five revolving slides; while one of them is in oil another comes out and the plate is taken out. Thus the plates worked out in a day's operation will all be maintained at the same temperature in going through the oil; after which they will be passed through the liquid bath in the drawing down process.

We all know that a carbon spring will not stand up with an alloy spring. During the past four or five years we have had made by the Pittsburgh Testing Laboratory both physical and chemical tests on the bar as it comes from the mill. During the past week I had occasion to make some tests for comparison between the bar as it came from the mill and after being heat treated. I was told by a prominent engineer that we could not get a tensile strength of 200,000 pounds, but I found that with a chromium vanadium bar two inches wide, the standard test

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length, we secured 133,000 pounds with the bar as it came from the mill, and 216,000 pounds after being heat treated.

H. D. HAIGHT.—One point in relation to calibration of pyrometers might interest the members. The practice at the Krupp Works is to check each morning each of the pyrometers in use in connection with furnaces for heating spring material. This checking is accomplished by means of a Siemens Water Pyrometer, which gives the true temperature of the furnace. The difference between this temperature and the apparent temperature as indicated by the regular furnace pyrometer, is the error which is added to or subtracted from the readings of the regular furnace pyrometer taken during the particular day.

# LUBRICATING OIL

BY HARRY TIPPER

(Member of the Society)

The work of lubricating oil in connection with any piece of moving equipment is always the work of conservation or reduction of waste. Probably that is one reason why in the growth of an industry the question of lubricating oil and lubrication receives less attention than similar questions in connection with other developments of the products of that industry. It always requires a little more analysis, more careful investigation and a somewhat keener appreciation of leakages to consider the saving of waste which might be made than it does to consider the improvement in the quality of the finished product. This is also undoubtedly due to the fact that the results are not so readily determined and the reasons for such results so readily appreciated.

In the case of lubricating oil this feature has been further complicated by the fact that it is only within the last year or two that engineers have begun to understand the variations in oils and the variations in the crude from which the finished oils are drawn.

Lubrication, of course, has for its one general object the conservation of power, or to put it another way, the reduction of frictional waste. The amount of lubricating oil used in the running of any machinery is so small that it has probably been neglected in favor of operations which involve much larger sums in the aggregate. A little study of the losses due to friction which occur in the moving equipment of any plant is sufficient, however, to show the enormous possibilities for the conservation of power and the reduction of waste, which lie in the examination of the conditions affecting lubrication and the quality necessary to meet it.

The efficiency of lubricating oil depends largely upon its ability to maintain a film between the metal surfaces, the extent of fluid friction in the oil film itself as against the friction of metal surfaces, and the amount of oil which is required to maintain the conditions of lowest temperature between the moving surfaces, and as a consequence, the saving

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of power due to the less absorption of such power in overcoming the friction.

In practical use the oil must vary according to the speed, pressure and heat conditions in the equipment, the amount of moisture, the mechanical arrangements for oiling, together with the question of settlement and filtration. Innumerable modifications may be necessary in the grade of oil required; for instance, the question of dry and wet steam in the cylinders of a steam engine, superheated steam, character of circulating systems, the fit and finish of bearings, etc., all exercise a modifying influence upon the oils which can be used. The accuracy with which the mechanical conditions are determined and the extent to which the manufacturer and his engineering corps are experienced, in the consequent requirements of oils to meet such conditions, are the bases for the successful solution of lubricating problems.

On account of the lack of study which has been apparent on this question, and also partly on account of the rapid extension in the number of fields from which oil is produced, and the better possibilities for comparison in that regard today, it is possible to consider some of the usual methods of determining the lubricating qualities of oils and show wherein they fail of giving any indications of the practical value of such oils under the conditions in which they are to be used.

## SPECIFICATIONS

The common method of specifying lubricating oil which has been in use for a great many years is to stipulate a certain gravity, flash, fire, viscosity and cold test, under the assumption, of course, that such limitations of the tests mentioned will have the effect of obliging the manufacturer to submit an oil which will do the work to the best advantage. A thorough examination of these tests, however, shows that they are not by any means conclusive of the value of an oil for lubricating purposes. In regard to some of them, the results are entirely misleading. The reason, of course, is easily determined. Some twenty years ago when practically all the oil which was in general use for lubricating purposes was drawn from Pennsylvania and adjacent fields, and was composed of practically the same hydrocarbon compounds with the same arrangements and was refined under much the same conditions, it was possible to compare two lubricating oils produced under these conditions by the arbitrary tests mentioned above, which were used by the refiner for his own convenience in measuring the uniformity and character of his runs. But the situation is entirely different. The fields from which the oil was drawn principally in those days supply only a very small percentage of the oil which is used today. The newer fields do not always deliver crude oil of the same characteristics either in a chemical or a physical way, and as a consequence these arbitrary tests no longer answer the purpose, as the different chemical and physical construction of the oils is sufficient to make any comparison on the same basis impossible. To put it briefly, such specifications are out-of-date. In the last twenty years new discoveries have been just as frequent

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in the oil business as in any other industry. New requirements have been imposed upon the oil refiner, owing to changing conditions in the equipment to be lubricated. It is consequently absurd to expect specifications which were permissible twenty years ago, under entirely different conditions, to be of any value to the buyer of lubricating oil today under new requirements and new possibilities.

### GRAVITY

Taking these tests in detail, let us examine the question of gravity in respect of the present day conditions. Gravity is simply the weight of the liquid in terms of weight of water. On the Baumé scale, which is the scale in practically universal use in the oil business, the gravity is expressed in arbitrary figures, with the lowest number on the scale representing water and the numbers increasing as the liquid becomes lighter in weight. Gravity was first introduced in lubricating oil specifications because in comparing oils made from the character of crude which was used at the time, it bore a relation to the viscosity or body of the oil. This is not true, however, of some of the other crudes which are now supplying a considerable proportion of the lubricating oil used, as in some of these crudes the viscosity or body may change from 200 seconds to 2000 seconds, while the gravity reading will remain the same. I have lately seen a sample of a crude oil which was heavier than most of the crude oil found and possessed at the same time no viscosity greater than water. Further, gravity bears no relation to viscosity whatever when comparing lubricating oil made from two different crudes. In one case a 29 to 30 gravity oil may run 180 to 200 viscosity, and in another case the same viscosity may be secured with a reading of 19 on the Baumé scale. The gravity reading is practically of no value to anybody but the refiner, who can and must use it in comparing the uniformity of his arms from the same crude. It has been proved through the gasolines, napthas and burning oils that it has no relation to their value for use, and in the last two or three years the same feature has been thoroughly investigated and proven in respect of lubricating oils.

### FLASH AND FIRE

The flash and fire tests are represented respectively by the temperature at which oil, being heated at a standard rate, with a standard flame, passed over it at a standard distance, will show a flash or flame from the gases rising from its surface, and the point at which the oil under the same conditions begins to burn.

From the standpoint of lubrication, the only bearing which the flash and fire tests have upon the oil under service, is to insure against the presence of volatile constituents which might begin to vaporize at the temperatures reached in ordinary work

### VISCOSITY

The viscosity test is represented by the length of time which is required for a specified quantity of the material to pass through a speci-

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fied orifice at certain temperatures, and the viscosity reading is always expressed as the number of seconds it takes the above-named conditions to be fulfilled. The viscosity of an oil has a considerable bearing upon its value for lubricating purposes, as it determines the speed of flow of the oil under certain temperature conditions, and it is obvious that the rate of flow of the oil is of great importance in considering conditions of pressure and speed in connection with all ordinary lubricating work. The trouble with the viscosity specification as it is used at present arises from the fact that the viscosity depends upon the temperature at which the oil will work, and if this temperature varies considerably from the standard temperatures at which the tests are usually made, there will necessarily be a great deal of difference in the usual working of the oil under the practical conditions involved. Furthermore, the variations in viscosity of lubricating oils made from different crudes are not the same for different temperature conditions. Finally, the viscosity of lubricating oils made from different crudes does not by any means indicate the fluid friction which is set up internally in the use of the material. In oils made from some crudes the characteristics of the oil change with the viscosity, whereas in oils made from other crudes the viscosity alone can be changed without affecting the other characteristics as shown in tests.

### COLD TEST

The cold test is of importance as demonstrating the ability of lubricating oil to remain fluid under conditions of exposure to low temperatures. Its value, however, depends entirely upon the work to which the oil is to be put. The cold test is sometimes made by reducing the temperature of the oil and taking the point at which it becomes cloudy; again by reducing the temperature and taking the point at which it refuses to pour out of a standard orifice in a standard quantity. The cold test is a question of the ability of the lubricating oil to meet the practical requirements of the working conditions, and it is evident, therefore, that an oil which will flow at a point in temperature as nearly as possible the minimum temperature experienced in actual conditions of use will be most valuable for the purpose.

The point, however, which should be noted in connection with all these tests on specification for oils is that they do not demonstrate the value of the oil under practical conditions, and merely put a limit upon the competition which can be secured or upon the amount of oil which can be drawn from for use, without in any way furthering the value or advantage. To put this matter concretely, engine oils manufactured from different crudes show the following variations in the characteristics:

| | |
|---|---|
| Gravity | 19° to 31° |
| Flash | 320° to 400° |
| Fire | 370° to 450° |
| Cold | 0° to 30° |
| Viscosity (on Saybolt instrument) or higher at 100° Fahr. | 120° to 750° |

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Within this range of characteristics oil suitable for all classes of engines can be picked out, and the question of their suitability would not depend upon the particular tests displayed by the oil. Two oils answering the same laboratory tests might show entirely different results in actual work, due to difference in the methods of manufacture not appreciable in a laboratory inspection; one would lubricate and the other would not.

## REQUIREMENTS

Inasmuch as the arbitrary tests to determine the physical characteristics of the oil do not illuminate its value for any particular purpose, let us consider what the oil should do. In order to bring this directly to the point of greatest interest to the Society, that is, the lubrication of the motor of automobiles, let me suggest the requirements which a lubricant for this purpose should meet:

1. The oil should possess a sufficient body to keep the bearing surfaces apart at the temperature at which the bearings run.
2. It should possess such qualities as will reduce the friction to a minimum.
3. The flash point should be sufficiently high to insure against the presence of volatile constituents.
4. It should remain fluid at such low temperatures as will be met in service conditions.
5. It should have no tendency to decompose or to form such deposits as will gum up the machine and increase the friction, where the object is to decrease it.
6. It should contain no ingredients which will corrode or pit the metal.

In considering the qualifications to be added to these general requirements in order to define application to the mechanical conditions of cylinder lubrication, it is necessary to consider the questions involved in the operation of an internal combustion engine, which are different from those of any other type. What I have to say now may appear very elementary from a mechanical standpoint, but unless it is mentioned, the important bearing which it has upon lubrication will not be as obvious as I want to make it. After a charge has been taken into the cylinder on the suction stroke it is compressed to from 50 to 75 pounds before being fired. Naturally upon the starting of the compression stroke there is a tendency for the gasoline mixture to leak. There are two ways of obviating this difficulty, of securing full compression. These two ways might be stated as mechanically secured compression, formed by the close fit between the piston or piston rings and the cylinder wall; or compression secured by liquid seal, which means the use of an easy clearance between the piston rings and the cylinder wall and the sealing of the space between them by the use of a proper kind of lubricating oil. In respect to the mechanically secured compression the following points are worth noting as axioms which must be taken into consideration in estimating the conditions:

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1. The closer the fit, that is, the less the clearance between the piston and cylinder walls, the more the power absorbed in turning the engine over. In fact, it is possible to secure perfect compression in this way only by securing so tight a fit that the mechanism will not turn. Even in practice good compression can be secured only at the sacrifice of some of the effective power.
2. The closer the mechanical fit between piston and cylinder walls the thinner a lubricating oil which will work its way between them. The thinner the lubricating oil the greater will be the wear and tear, because of the impossibility of keeping the metal surfaces apart where the clearances are so small and the lubricant must be such a slight film.

With these conditions, when wear and tear has once begun, every stroke of the engine increases the loss of compression, the consumption of lubricating oil, the consumption of gasoline, in proportion to the amount of power, and, in fact, decreases continually the efficiency of the motor. You will readily see the impossibility of securing and maintaining maximum efficiency under the conditions.

The motor after leaving the factory is run at great variations of speed and considerable variation of load. These variations are quite rapid and frequent. On account of the mechanical conditions of the motor you have recommended a very thin, light lubricating oil for the motor, under the guarantee. This lubricating oil has no particular adhesiveness and will flow as readily from the cylinder wall as to it. Consequently, during the rapid and frequent variations of speed, cylinder walls are sometimes overburdened with oil and sometimes practically dry, making wear and tear excessive and naturally resulting in a very rapid increase in the space between the piston and cylinder wall. This wear and tear is not thoroughly even; the clearance is larger in some places than in others. Then the lubricating oil flows freely up and down the walls of the cylinder and there is never any time when just the proper amount of oil is on the cylinder wall. The oil is so thin that it cannot be held in the increased space, consequently on the compression stroke the gasoline mixture escapes past the piston, destroying the lubricating oil in the crankcase, and reducing from 15 to 30 per cent. the power which should be secured from the gasoline. You have seen from time to time in your experience with races, racing motors, etc., that after a three or four hours' run the oil in the crankcase has had to be dumped because it was so light in body as to be like water. I have heard some drivers, and also some engineers, thoroughly well acquainted with the motor, try to explain this fact by saying that the oil decomposed. Such a thing is, however, unknown in the oil business. In all other cases of the use of petroleum oils for lubricating, length of use only makes the oil a little heavier and a little darker in color. In no case has it ever been found possible to use an oil for lubricating purposes and secure a lighter product. This can be done by admixture only. In the course of our work in the recommendation of oils for motor purposes we had occasion to notice this peculiarity, to test it out, and found it almost invariable.

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Taking samples of oils at the beginning of the tests (all the tests being made with a 6-cylinder 60-horsepower automobile engine, arranged on the block with brake, necessary tachometers, measuring and weighing instruments, thermometers, barometers, and all requirements for thorough reading during the course of the test) and analyzing them; taking samples at the end of the tests and analyzing we found a reduction in the flash and fire of from 100 to 150 degrees, showing the presence of volatile constituents, a great reduction in the viscosity, so great in general as to have destroyed largely the lubricating value; and upon distillation a certain amount of product answering to the gasoline test was recovered.

### CARBONIZATION

Further, the condition under discussion is responsible largely for the carbon which is so constantly being experienced on account of the fact that the oil, being very light in body and free-flowing, is drawn up during the suction stroke into the compression chamber and on to the piston head, where it is distilled, leaving a coke baked on the piston head to the first ring, upon the valves, etc.

Consider instead of the mechanically secured compression used in connection with thin oil, compression which depends upon the use of lubricating oil, the clearances being larger. From the standpoint of the mechanical efficiency of any power generator, and, in fact, any moving equipment, the best fit—that is, the mechanical fit which absorbs the least amount of power due to friction in the power generator itself—is an easy sliding fit. If dependence is to be laid, however, upon the metal and not upon the lubricating oil to maintain compression, this easy sliding fit is too loose to give the compression required. If, however, it is intended to secure the compression by the liquid seal of the lubricant, then an easy sliding fit can be given to the motor, a sufficiently heavy-bodied oil used for lubricating with the result that the metal surfaces can be kept apart, the compression can be maintained so that there will be practically no change in the lubricating oil in the crankcase and only the ordinary wear and tear on a properly lubricated surface will take place, which wear and tear is infinitely slower than the wear and tear which usually occurs under the conditions previously mentioned.

In working out lubricating oils for automobile engines we are using today oil of 200, 300, 500 and 750 viscosity; the oil of 200 seconds viscosity being used entirely for those motors which are being made with clearances too small to permit of the oil of the proper body being used. Thousands of tests by private owners, which, while they may not be accurate, indicate the general result that in practice by the use of these heavier oils they have secured from 10 per cent. to 20 per cent. and in some cases over 30 per cent. more power from the fuel, owing to the saving of any loss on the compression stroke. On this account they have also used less lubricating oil, due to the fact that there is no admixture of gasoline, deterioration consequently being very slow. There is also less wear and tear on the cylinders and practically no trouble from carbon.

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When we first got records of 16,000, 20,000 and 25,000 miles with one set of spark plugs, and no carbon trouble, although some slight deposit, we were apt to put the figures down to enthusiasm and question their accuracy; but with the number of automobiles we ourselves are using, with the tests of which we have been able to keep some accurate control, and with the reports received, of which we have no means of knowing the accuracy, it is evident that the carbon trouble, as far as we are concerned, has been practically eliminated by the investigation into this question of mechanically secured fit or liquid seal for compression and of the deterioration of oil in the crankcase. As an added advantage of this we have found one of our crudes more particularly applicable to this class of work than any other and the adoption of this crude for motor oil has opened up to us a great many new possibilities, and some of the success which we have had in improving the lubricating conditions has been due, undoubtedly, to the character of the crude and its value for the purpose.

### CLEARANCE AND VISCOSITY

Nevertheless, it remains true of all our tests, experiments and information that the general practice of the motor manufacturer in this country has been to use clearances between piston and cylinder wall which were entirely too small and to use lubricating oil which was entirely too thin. This was undoubtedly due, to the attempt to get away from carbon troubles and gummy deposits, but a little reflection will show that the excessive carbon troubles are mainly to be connected with too thin an oil. While oils from some crudes, of course, give only soot, and other oils give coke when burnt in the combustion chamber, the carbon in each case is due to the presence of oil where it has no business to be and where under proper mechanical conditions it would not arrive. Provided the oil has sufficient body to adhere to the cylinder wall and the piston rings so that at all times a perfect, or practically perfect, seal is maintained, practically no oil should get up into the compression chamber, onto the valves or the piston head, inasmuch as if the oil has sufficient body to adhere to the cylinder walls during compression it will have no tendency to climb during the suction stroke, and consequently at no time will there be any large amount of excess oil where it will be affected by combustion. I have no doubt whatever that the motor manufacturer has in the past made a mistake in pressing the oil companies to give him a product which would not deposit any carbon, instead of examining the mechanical conditions of his motor and finding out whether it was necessary to burn oil. Under some conditions it is impossible to avoid carbon. The character of the carbon depends partly upon the character of the crude, the method of refining and the character of the oil made necessary by motor mechanical arrangements, but the cause of the continued presence of exeessive carbon and continual trouble with carbon should be looked for, it seems to me, in the mechanical conditions of the motor. When these mechanical conditions are examined it will be more fully determined that we have not been securing the economy which should be secured from the fuel or the

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lubricating oil and that the depreciation due to excessive wear has been too rapid.

### TESTING RUNNING LUBRICATING CONDITION

In connection with the testing of lubricating oil, the amount required to actually lubricate the cylinder, the amount wasted in cylinder lubrication, etc., we have been using an instrument (a sample of which I have brought with me for the examination of the Society members). This instrument is placed on the petcock above the exhaust valve and a piece of paper is placed in the slot arranged for same. The valve is then opened so that the explosion impinges upon the paper, which is held at the point for 12, 20 or 50 explosions, as the case may be, the paper being a standard distance away from the opening. The result secured is a picture showing the amount of excess lubricating oil in the compression chamber, the amount of carbon in the compression chamber, and consequently the lubricating conditions during the explosion stroke. Having considered these pictures in connection with variation of the lubricating condition and the character of the oil, it is possible to secure readily a condition of greatest lubricating efficiency and keep a continual sheet of the progress of a run on the block and the results from a lubricating standpoint. This instrument, if used in conjunction with a dynamometer test, so arranged as to show the variations in power and speed secured by different lubricating conditions, will enable the engineer to maintain a control of his experiment which we have not been able to do in any other way and which opens possibilities for future investigation that are of considerable interest

### DIFFERENT KINDS OF PETROLEUM

I would like to correct a rather erroneous idea which is extant as to the distribution of different kinds of petroleum in the United States. It is generally considered that there are three divisions of the type of petroleum; that is, the type which is found in Pennsylvania, in the eastern states; the type which is found in the Middle West, and the type found in California. This is entirely erroneous. There is no special type of petroleum crude which contains any certain characteristics or range of hydrocarbon compound peculiar to any one particular field. There are, for instance, in the Midcontinent and Southwest something like fifteen different fields, covering something like five different types of petroleum. The paraffine-base petroleums are found in Pennsylvania, in Texas and in Louisiana to some extent. The asphaltic-base petroleums are found in California, Mexico and Texas. The semi-asphaltic-base petroleums are found in the Midcontinent fields, to some extent in California and to some extent in the eastern field. There is no definite range and it is possible to secure just as many different kinds of crude from the Midcontinent and Southwestern field as it is from the rest of the country. In other words, the paraffine-base crude is not exclusively confined to

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Pennsylvania, nor is the asphaltic-base confined exclusively to California. This understanding is necessary in order to appreciate the conditions which prevail in the oil industry today.

# JACKSHAFT VS. DOUBLE REAR-WHEEL BRAKES

By Arthur M. Laycock

(Member of the Society)

An investigation from a designer's outlook on the following lines may prove instructive:

(1) Danger of braking through any intermediary and not direct.

(2) The detrimental effects of brakes on end of jackshaft.

(3) Effect on universal joints and differential gears.

Our government in its specifications for army trucks has without any question taken the right step in insisting on both brakes being on the rear wheels. This must have a beneficial effect on the trade in general. Similar enactments should be made in all our large cities to save property and life in congested streets. Imagine New York and Chicago motorized, the average speed changing from 3 to 12 miles per hour. Not only capable brakes but proper location as well will be insisted upon. The reaction due to the frictional force on the brake surface should be as close to the road wheel as possible. Obviously, the closer the point of application of the braking force, and the point of its final reaction, the fewer the parts subjected to strain, which means not only a minimum number of breakdowns, but the greatest possible safety to the operator and the public at large.

It is equally objectionable to brake through the bevels, spur gearing, double reduction gears, and the worm drive as applied to heavy vehicles; in fact, in these constructions it is not only dangerous in the extreme, but absolutely wrong when one considers the enormous strain of a reversible nature coming from the rear wheels when the propelled-shaft brake is locked. Of course, most engineers will say that it is easy to make these parts heavy enough, but the writer cannot see the logic of adding this unnecessary weight, and, at the best, you have an uncertainty with every unit between the brake and the road wheel, which in some constructions is quite alarming, no matter what proportion, material or treatment these parts may have. In taxicab service, particularly in New York City, the propeller-shaft brake, which is so popular in Europe, has practically been discarded for both brakes on the rear wheels.

Whatever may be the status as to brake location on the pleasure car, there is no comparison between the energy stored up in a 6-ton machine and the heaviest of pleasure cars. In case of collision at a given speed the disastrous possibilities of brake failure are more pronounced in commercial than in pleasure car work.

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DETRIMENTAL EFFECTS OF BRAKES ON END OF JACKSHAFT

Most designers, I believe, are influenced by the popular trend, forgetting their own figures in a desire to give not what is called for, but what is easier to obtain. Both brakes on the rear are more difficult to design efficiently. One has only to notice the diagram below to see the disastrous effects a jackshaft brake has on the bearings, shafts, etc. Engineers, who have really had the courage of their convictions and put in sections to correspond with the forces, have finished with tremendously heavy construction, leaving the impression that they were inclined to be nervous about the jackshaft ends and careless with the real thing; in other words, dismantle from one of our best trucks a jackshaft with brake thereon and you will be struck very forcibly with the size of the outer ends as compared with the bevels, which are the real weak point in a good many designs, particularly where heavy engines are used and only a four-pitch bevel. Startling as the figures below may appear to be these facts remind one that perhaps they are nearer right than one would think if guided by the figures only.

Where semi-floating construction is used, which is preferable in the writer's opinion, on account of being able to use a much smaller sprocket and put the grief in the chain instead of in the delicate differential gears and driveshafts, the combined bending and torsion at the end of the jackshaft calls for a diameter that is very rarely taken care of properly. Many designers have the opinion that you can take a pleasure car axle and use it as a jackshaft. This is all right if jackshaft brakes are not used, the conditions then being analogous to pleasure car work so far as the jackshaft ends are concerned; in other words, you can never impose strains greater than the full torque of the motor. But with the jackshaft brake you may exceed this from two to three times; the larger the truck the more pronounced, of course, is the difference. Figures based on a 6-ton truck are so glaring in this respect that the outer ends must be so large as to be out of all proportion to the rest of the truck.

Take, for example, a 6-ton truck, 50 per cent. overload, 80 per cent. on the rear, which would be equal to about 10,000 pounds on each wheel; 40-inch rear-wheel diameter, sprocket diameters 6 inches and 22 inches, countershaft brake drum diameter 12 inches, and coëfficient of friction between the road and the tires 75 per cent.

Considering the jackshaft brake first.

$$\text{The pull on chain} = \frac{10{,}000 \times .75 \times 20}{11} = 13{,}650 \text{ lbs.}$$

The horizontal component of 13,650 lbs. = 13,300 lbs.

$$\text{Reaction on fulcrum pin } A = \frac{13{,}300 \text{ lbs.} \times 3}{6} = 6{,}650 \text{ lbs.}$$

Plotting the above forces—Fig. 1—the resultant reaction on the sprocket bearing is 19,950 lbs.

The distance from the center line of the sprocket to the center line

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of the sprocket bearing being 3½ inches, and the distance from the center line of the sprocket bearing to the center line of the countershaft 20 inches—Fig. 2—the total load on bearing is equal to

$$\frac{19{,}950 \times 3\frac{1}{2}}{20} + 19{,}950 = 23{,}445 \text{ lbs.}$$

Considering a motor of 50 horsepower, 1,000 r.p.m., with a 12:1 reduction, that is, 4:1 in the bevels and 3:1 in the transmission, we obtain

$$\text{Pull in chain required in driving} = \frac{50 \times 63{,}000}{83 \times 2 \times 3} = 6{,}300 \text{ lbs.}$$

You will notice that in the double rear-wheel brake construction it is utterly impossible to impose any load whatever on the jackshaft ends except, of course, the reaction from the radius rods, which can be taken easily direct on the frame. The figures given undoubtedly account for the many failures as well as for the exceptionally large brackets used by some. Almost 12 tons is quite an item to take care of. It seems perfectly absurd to introduce these strains on the end of the jackshaft and more than double the work on the chain. Where pleasure car axles, with brakes attached, have been used for jackshafts there has been more or less trouble. The bearings, tubes and drive-shafts are subjected to stresses they were never designed for.

In the above paragraphs I have endeavored to demonstrate conditions the jackshaft brake imposes on the surrounding parts. This has not been considered by any means from every angle, but sufficiently, I think, to show the superiority of the double-brakes-on-the-rear over the jackshaft brake design. It is manifest that the wheels are the only place for the brakes, spelling finality in design as to their location, unless dependability and cost be sacrificed in the extreme.

### EFFECT ON UNIVERSAL JOINTS AND DIFFERENTIAL GEARS

In making a diagnosis of the situation pertaining to propeller-shaft brakes, the same questions may be asked and like answers returned as in the case of jackshaft brakes. The question may be raised as to the propeller-shaft brake eliminating to some extent the tendency of skidding. This, of course, opens up a very debatable question upon which few engineers agree. I think there is not much to choose between braking through the propeller-shaft and both brakes on the rear provided with a differential brake rock shaft; whether we take the conventional differential and differentiate by resistance, or take one which equalizes to velocity, the car will most certainly have the same tendency to skid if the coëfficient of friction for each wheel on the road varies. It is obvious that the durability of joints and gears must be sacrificed with the propeller-shaft brake, and I am sure that a good equalizer on the brake rock shaft with double brakes on the rear wheels leaves nothing to be desired so far as side skidding is concerned. Some of our largest makers having always retained this construction. The excessive wear and ultimate failure of

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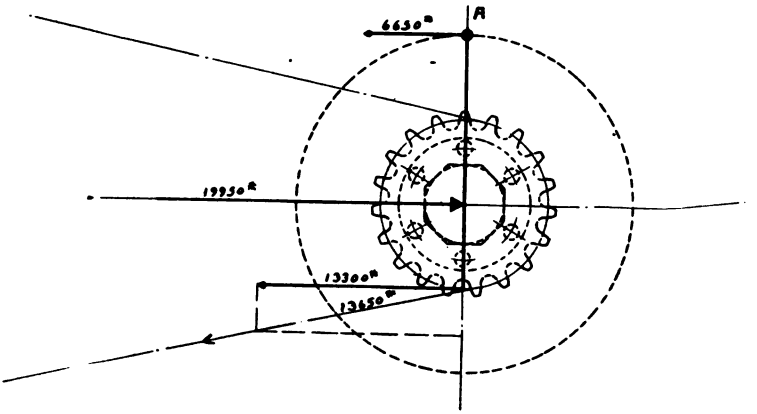


Fig. 1

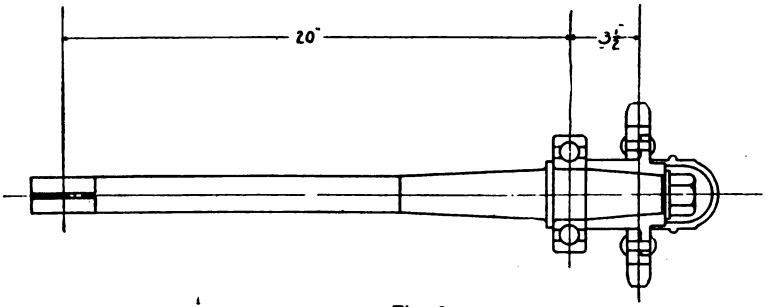


Fig. 2

universal joints subjected to the reversible strains are easily accounted for. The unit pressure per square inch in most of the joints is exceedingly high. In fact, it is quite ordinary practice to work at 3,000 lbs. per square inch. This figure is almost the limit and necessitates forced lubrication in some constructions. Nothing but hardened steel on bronze or hardened steel on hardened steel will stand this. Happily these loads are only momentarily applied. I have recently found that one of our leading and successful parts manufacturers recommend power transmission on their joints equivalent to 4,400 lbs. pressure per square inch with a reduction of 3 : 1 in the transmission. Imagine the results when you increase the pressure 200 per cent., which again is putting things rather mildly as compared to what actually occurs with our heavy limousines and worm-driven trucks.

The replacement of joints, however, is not so expensive or troublesome as the repair of broken differential gears. Precisely the same theory

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holds good here; most of our differential gears are working under exceedingly high pressures. In fact, it is quite common practice to work at from 75,000 to 100,000 lbs., the stresses being the resultant of the full torque of the engine and the reduction in transmission. The steel used here will probably range from 100,000 to 150,000 lbs. per square inch elastic limit. Very few makers have a greater factor of safety than 2 : 1. These parts are also subjected to the same 200 per cent. overload from the rear, which you will admit must be a pretty warm place for gears already stressed to 100,000 lbs. per square inch from engine torque alone. Considering that these extreme loads are of a reversible nature, it is very surprising the gears stand up at all, speaking well for the grade of steel used and the particularly fine heat treatment obtained in our large factories.

The drive-shafts are usually stressed very high, even in the full-floating type. In the semi-floating construction the combined bending torsion is very rarely taken care of adequately, figuring from the road-wheel end, whereas it may be quite safe as to taking the torque of the motor only. Take, for example, a 5-ton worm-driven truck, of approximate weight with body of 8,000 lbs.; figuring 25 per cent. overload and 80 per cent. on the rear, which in round figures comes out 8,000 lbs. per wheel; using an engine of 4⅞ inches by 6 inch, four cylinders, which will develop 47 horsepower at 1,000 r.p.m.; reduction in first gear 3.77 : 1, and a ratio of 8 : 1 in the axle; the diameter of the propeller-shaft 1½ inches; diameter of pitch circle on worm 3 inches, and diameter of rear wheels 40 inches.

The torsion moment in propeller-shaft from the engine on low gear would equal

$$M_t = \frac{47 \times 63{,}000}{265} = 11{,}300 \text{ inch-pounds.}$$

The torsion moment in propeller-shaft from road wheels equals

$$M_t = \frac{16{,}000 \times 20 \times .75}{8} = 30{,}000 \text{ inch-pounds.}$$

$$\text{Stress in propeller-shaft from engine} = \frac{11{,}300 \times 5}{1\frac{1}{2}^3} = 16{,}700 \text{ lbs. per sq.in.}$$

$$\text{Stress in propeller-shaft from road wheels and propeller-shaft brake locked.} = \frac{30{,}000 \times 5}{1\frac{1}{2}^3} = 44{,}000 \text{ lbs. per sq. in.}$$

$$\text{Tangential pressure on teeth} = \frac{11{,}300}{1.5} = 7{,}420 \text{ lbs. on low gear.}$$

$$\text{Tangential pressure on teeth} = \frac{30{,}000}{1.5} = 20{,}000 \text{ lbs. from locked wheels.}$$

Of course, the question might be brought up that under this load of 20,000 lbs. there is no motion, the wheels being locked, but in mountainous country, I think you will agree with me, it is quite customary for a man to slide his wheels intermittently, and I am sure we can have considerable

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speed between the surfaces in contact and pressure very close to this. Many follow this construction in England at the present time, and it would be interesting to have our English friends' views on the subject. Where this design is used it undoubtedly speaks volumes for the dependability of worm gears as applied to heavy vehicles, considering they may be subjected to pressures from three to four times more than in the case of the double-brakes-on-the-rear-wheels construction. The high stress in the propeller-shaft is quite easy to take care of, but it is mighty hard on joints, differential gears and bearings.

In making road tests of a new chassis, the brakes are one of the principal factors, and abused in an extraordinary manner with the roughest possible treatment. One can very easily imagine the anxiety of a designer of a propeller-shaft brake in comparison with one of both brakes on the rear. The former has the propeller-shaft, bevel pinion, ring gear, differential housing, differential gears with their bearings and drive-shafts in mind, while the latter is absolutely free from these considerations. In almost every item throughout the design of a chassis the engineer has in mind that the only way to obtain results is to cut down to a minimum the number of parts subjected to strain, or, in other words, to take the shortest distance between two given points.

The above discussion may be radical, but will seem quite in order to anyone who has handled an overloaded car in mountainous country, where an amateur will de-clutch and roll backwards for a considerable distance and then apply the brakes violently. An observer watching the manipulation of a robust jackshaft or propeller-shaft brake, coupled with a fierce clutch on a 25 per cent. grade, and the weight thrown on the rear wheel—as much as 80 per cent.—is led to surmise that the only logical design to stand abnormal shocks is the one involving the minimum number of parts subjected to the strains. To see a 6-ton machine under these conditions is an event not easily forgotten by any designer; words are inadequate to express the frightful abuse machines have to stand under the conditions enumerated.

The writer is absolutely unable to account for the propeller-shaft or jackshaft brake. There appears to be very much against them and very little in their favor.

## DISCUSSION

PRESIDENT MARMON.—Mr. Laycock's views are much in accord with my own.

THOMAS CLARKSON.—Mr. President and gentlemen: I quite appreciate the argument in favor of having brakes directly on the wheels. At the present time our design has been worked up pretty largely under the influence of police regulations, and it has been possible to save weight by using the jackshaft brake instead of putting on another drum with large bands. I do not know that I can seriously criticize what Mr. Laycock says. I think there is a great deal to be said for it. But at the present time we are using the propeller-shaft brake satisfactorily. It has been

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stiffened up. We at one time used cast iron drums on account of being cheap to renew. That was a long time ago; the drums we use now are drop forged. We have reinforced the gear a great deal. First we used copper-lined shoes. Now we use a lining material of woven asbestos and wire which answers satisfactorily.

PRESIDENT MARMON.—You use that, however, as an emergency and not as a service brake.

THOMAS CLARKSON.—No, not as a service brake.

C. T. MYERS.—I agree entirely with Mr. Laycock's exposition of the subject. I have seen a lot of trouble with jackshaft bearings. I think it is traceable directly to the subjection of the jackshaft and those bearings, to stresses which they were never designed to resist. If I had my way in designing a double-side-chain-drive truck I would never put the brakes on the jackshaft. It has the further disadvantage of making a bad take-down job. A great many designers will figure only to a limited extent on the cost of taking-down. The cost of assembling is important to the manufacturer as a factor of profit. It is very important, however, to the manufacturer that the man who buys his work shall be able to repair and in many cases take down and reassemble important parts in the least possible time. The jackshaft brake militates against this important feature. But even so far as braking strains and stresses are concerned, I think there is no comparison, and I am surprised that the matter has not been brought up before.

THOMAS CLARKSON.—I would like to ask, Mr. President and gentlemen, whether in this advocacy of both brakes being on the wheels, the custom is to have two drums or only one.

C. T. MYERS.—I approve of both brake shoes operating on the inside of one drum.

THOMAS CLARKSON.—That is not held to be two independent brakes. If anything happens to that one drum, you are done.

C. T. MYERS.—Yes, but there is always a possibility of something happening to something. It is so remote, however, that to my mind the objection of the London police (to which I presume Mr. Clarkson refers) is very far fetched. The single drum can certainly be made to stand up, as repeatedly demonstrated, and it has the prime advantage of simplicity.

C. H. TAYLOR.—With regard to the last point, I cannot see what could possibly happen to the drum except to either split or wear out. If it splits it becomes an automatic jaw clutch and stops the whole outfit. If it wears out, it does so slowly. You have two brakes there, two surfaces to wear out. It would seem that the London regulations in regard to that are somewhat arbitrary.

With regard to Mr. Laycock's paper, I personally have no very strong feeling one way or the other with regard to the position for truck brakes. I believe that you can get a very much more nicely operating foot-brake, where you have a limited throw of the pedal and a limited foot pressure, with a heavily loaded truck, by putting the foot-brake on the shaft, that is by getting a high-speed surface. I believe that is the main reason for the shaft brake. From what I have seen of truck driving I think that it

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is going to be a rather difficult thing to get a well operating brake on the rear drum on the wheel, when operated by foot pedal. For an emergency hand lever brake it is all right; you have a motion of eighteen or twenty-four inches at the end of the lever and are able to exert almost the same load with the hand that you can with the foot; that is, in extreme cases, when a man gets tugging at it. Enough power can be applied through the long swing of a hand lever to set the wheel brakes with the required tension for heavy trucks and to move the linkage sufficiently to avoid constantly adjusting for wear. This is next to impossible on trucks of over two tons' capacity by means of a pedal, owing to the short swing available.

With regard to the calculations that Mr. Laycock has made, it seems to me that they themselves are all right but are based upon rather extreme assumptions. He assumes, for instance, that the brakes will skid the wheels on a seventy-five per cent. coëfficient. I think seventy-five per cent. coëfficient of friction of the wheels on the ground is unnecessarily high in the first place. Secondly, I think that with any good truck it should be possible to spin its wheels with normal load or slight excess load on ordinary pavements with fifty per cent. coëfficient or less. In this assumption the friction stresses are the same as the motor stresses, approximately, but in the reverse direction. It seems to me that the main point is that the reversal of stresses is a good thing to be avoided in all the joints, and that the jackshaft brake when used as a service brake does reverse the stresses much more than they would otherwise be reversed. Consequently, with the chain drive, of course, the wheel brake takes the stresses off the chain and sprockets. A chain and sprocket badly worn will work fairly well when they are pulled continuously in one direction, operating in one direction. The instant the jackshaft brake is thrown on you get a very nasty jerking action that very frequently breaks chains, not due to the exertion of torque stresses, but to the faulty meshing of the chain with the worn sprocket.

C. T. Myers.—I would like to say something about the comparison of stresses in starting or in driving on the low gear, with those encountered in braking. We owe a good deal to our English brethren. There is one whom I would like to mention, Mr. Wimperis, who has designed a small instrument called the accelerometer. I have made some tests with it on trucks and on other cars on which jackshaft brakes were used, and find almost invariably there is two and a half to three times as much force exerted in stopping as there is in starting. It is a very unusual case wherein the force due to the acceleration in starting or in pulling is anywhere near equal that due to the sudden application of the brakes where the road surface is good (macadam, for instance).

Now, this instrument, I think, will be of great value to the members of this Society in testing out the actual condition of machines on the road. They will find out a number of things which they only conjectured before, and which they had not had means to check. I was going to ask whether the acceleration test to which our English brethren refer was made by any such method or simply by sitting on the seat and estimating a comparison?

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By acceleration do you mean the general impression which the public gets or do you refer to figures, which can be used for definite comparison?

THOMAS CLARKSON.—Definite measurements. I cannot say which instrument was used in the bus tests. The tests to which I referred, made by the London General Omnibus Company, were made as scientific tests.

C. H. TAYLOR.—I would like to call attention to the fact that the accelerometer necessitates probably greater delicacy than it would be possible to use in a motor car of any kind, and would not give you any indication at all of the maximum stresses in the driving system. I base that on the fact brought out here, and there is no question about the fact, whether it is a pleasure car or a truck, that when you slap the brakes on for all you are worth on a dry pavement, you get a retardation that is vastly greater than the normal acceleration you get in handling your car, no matter what you do, unless you spin a heavy flywheel and jerk your clutch in. In experimenting with a jackshaft, putting an indicator on the ends of the spring-supported torque-arm we have found that the maximum reactions on the jackshaft are positively greater in the driving direction than they are in the braking direction. In my experience of the last ten years with bevel-gear-driven cars, I have seen probably ten or fifteen torsion members bent and broken. I think that just one in the whole lot was bent in a downward direction. All the others were broken or bent upwardly, due to harsh clutching, that is, excessive driving stresses.

A. M. LAYCOCK.—That might be so in the case of a light pleasure car, but with a heavy truck it is quite different, where the torque is greater from the rear wheels than it is from the engine.

C. H. TAYLOR.—I maintain that the torsion moment in a properly designed truck will never be greater, because in both directions you should be able to spin the wheels with a slight overload. In other words, I claim that you have not a properly designed truck unless you can do that. I am not now speaking of English conditions, I am speaking of conditions that any truck is bound to meet in this country, getting in the sand, down in a ditch occasionally and sliding off roads. If you are going to make a truck that is to be serviceable throughout this country under abnormal conditions and ordinary circumstances, the motor must be able to spin the wheels with a 50 per cent. coëfficient and a 20 per cent. overload.

A. M. LAYCOCK.—I think that if you take half a dozen leading makes in this country, you will find that that is not so. In almost every case the torsion moment is considerably greater from the rear than it ever can be from the engine. That is, figuring on 50 per cent. overload and 80 per cent. on the rear, with a coëfficient of friction of 75 per cent. I note Mr. Taylor mentions 50 per cent.—this is really too low. I believe 75 per cent. is quite in order when block tires are used.

C. H. TAYLOR.—With such conditions assumed I do not believe you could make the wheel brakes lock the rear wheels; unless the linkage were designed to give so small a movement to the brake jaws or bands that constant adjustment for wear would be required.

A. M. LAYCOCK.—One has only to notice the figures in regard to the

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5-ton worm-driven truck, as indicated in my paper. These figures have been taken from a very successful and exceptionally well designed heavy American truck.

In braking on a down-grade the bulk of the load is on the front axle, and the torsion moment due to braking can never be as great as when the truck is rolling backwards down an incline with the bulk of the load on the rear axle. This in almost every case constitutes a greater strain on the torque members than could have been brought on by the reaction of the engine, and accounts for their failure in an upward direction. I think Mr. Taylor has also overlooked the fact that there is no comparison between the energy stored up in a 5-ton machine with a 50 per cent overload descending a steep incline at 12 miles per hour, when the jack-shaft brakes are instantly locked, and the reaction from the energy derived from the acceleration of the driving mechanism. In his remarks in regard to the accelerometer he admitted a greater retardation from the brakes than acceleration in handling a car, no matter what you do, unless you spin a heavy flywheel and jerk the clutch in.

I maintain, as I said before, that it is impossible to put the same torsion moment on the drive-shafts of a 5-ton worm-driven truck with a flywheel of normal dimensions, no matter how you may jerk the clutch in, or from the braking strain with a propeller-shaft brake, when figuring with a 50 per cent overload.

In regard to Mr. Taylor's comment as to not being able to lock the rear wheels under these conditions, it is well to note that if you have a movement of not less than 6 inches on the pedal, you can easily stop a 5-ton truck, with about 150 pounds pressure on the pedal, using a 20-inch drum on a 40-inch road wheel, even figuring 80 per cent. on the rear and 50 per cent. overload.

A MEMBER.—What kind of brake friction surface?

A. M. LAYCOCK.—The figures were estimated with a coëfficient of friction of .23.

# MOTOR TRUCK WHEELS

BY ARTHUR J. SLADE

(Member of the Society)

This paper is the outcome of the writer's temerity in offering a suggestion to the Commercial Car Wheels Division of the Standards Committee, that, in considering the standardization of metal wheels, along lines similar to the standardization of wood wheels, certain practices, as to material and design, should be recommended for the benefit of the motor truck designer.

A precedent has been established by the Iron and Steel Division of the Standards Committee, in recommending good engineering practice; as for example:

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"Steel castings for axles, crankshafts, and steering spindles are used only at a great risk."

The chairman of the Commercial Car Wheels Division, and the Secretary and General Manager of the Society, did not, however, view the proposal with approval, but suggested a paper for presentation at this meeting, with a view to bringing out available information as to suitable material and designs for truck wheels, through those members best qualified by experience to express themselves on the subject with authority.

It is perhaps natural that wheels built of wood should have been developed to a high state of perfection in this country where such a large and varied supply of wood is available. The rapid development of the West called for vehicles of rugged and sturdy type for the pioneer's use in opening up a country without roads of any sort. Later the transportation companies, operating stage coaches over roads little more than trails, as new sections were settled, and eventually the agriculturist, who even now often operates his farm wagons over roads unworthy the name, demanded the highest quality of wheels.

The majority of the motor trucks built in this country have been equipped with wooden wheels; the earlier wheels conforming closely to the design of horse-drawn wagon wheels, especially with regard to size of spokes, but also, in some instances conforming to wagon-wheel practice even to the extent of wooden hubs. Some of these wheels, dating back perhaps ten or twelve years, are still in service on motor trucks in New York City.

## DEVELOPMENT OF WOOD WHEELS

The first radical improvement was in the substitution of metal for wood hubs, primarily to make possible the use of anti-friction bearings. Next came a radical change in the matter of spokes. When it is considered that a wagon wheel on a 5-ton capacity vehicle seldom has a tire exceeding 4 inches in width, whereas the tires on the 5-ton motor truck will usually total from 10 to 12 inches in width, it becomes obvious that the wide felloe on the truck wheel should be supported by a spoke of much greater width than the narrow felloe of the wagon wheel. Since 1907, when the importation into America of one of the most successful European trucks began, the improvement in the design, as well as construction, of wood wheels has been very marked. At that time one of our leading wheel builders undertook to practically duplicate these European wheels with spokes about 5 inches in width, flaring at the outer end so as to form an adequate support for the felloe, and also of sufficient cross-section to ensure a good shoulder on the end of the spoke against the inner surface of the felloe. Ever since that date the wheel builder in question has been manufacturing wheels, from designs similar to this, with great success; and, although some other wheel builders contended at the time that it was not feasible to procure wooden billets of a size suitable to finish spokes of such unusual dimensions, the majority, if not all, of the wheel builders catering to the motor truck industry are now building wood wheels of this general type.

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## EARLY METAL WHEELS

It must not be assumed, however, that the practice of motor truck builders in this country has been confined exclusively to wooden wheels. As far back as 1858 and 1862 motor trucks are reported to have been built, in an experimental way, with steel wheels. In the years 1903 and 1904, when the motor truck industry in this country was making a definite commercial start, the Gibbs Engineering & Manufacturing Company equipped trucks with cast steel and steel disk wheels. The cast steel wheels were similar to those now being advocated by several manufacturers, having hollow spokes integral with hubs and felloes. They were made of crucible steel and used a tire constructed from a combination of wood, steel and rubber. About twenty 5-ton trucks were built and the wheels were found to be on the whole satisfactory. The disk wheels were made of boiler plate, riveted to cast steel hubs and to a steel tire band. These wheels were also said to have given satisfactory service, but the company building the trucks in question no longer exists. One of our members who was identified with the production of these vehicles will, it is hoped, contribute some discussion on this paper.

In 1905 the Couple-Gear Freight Wheel Company brought out a line of trucks equipped with wheels made up of steel plates. In the interior of the wheels an electric motor was mounted, and this same construction has been followed by that company up to the present date. At about the same time the Four-Wheel-Drive Wagon Company, of Milwaukee, brought out 5- and 10-ton capacity gasoline trucks equipped with wheels on which the tires were segments of rock elm and the side plates were steel disks. This company is not now in existence.

In 1906, a metal wheel, known as the "Indestructible Steel Wheel," was introduced to the market in Chicago. These wheels were built of side disks of steel, reinforced inside with structural shapes; the various members of the wheel being riveted together. They were used on trucks built by the Reliance, Commerce, Rapid, Plymouth, Grabowsky and Packard companies, of which all but the latter have discontinued manufacturing, and the Packard company only used a limited number. The Rapid company is said to have continued their use the longest, covering a period of about two years. The severe strains and shocks due to irregular road surfaces are reported to have loosened the rivets holding the various members together, and the wheels were not found to be permanently satisfactory. It is hoped that some member of the Society present may have had personal experience with this type of wheel and can give us information regarding its value.

In 1908 the Morgan truck of 5-tons capacity was brought out with a disk type of cast steel wheel which proved unsatisfactory and was superseded in 1910 by a cast steel wheel with spokes of the general design with which we are familiar.

In 1909 the White company introduced steel wheels on the larger sizes of their commercial vehicles. It is understood that modification of the design of these wheels was necessary to eliminate breaking of the spokes

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near their point of union with the felloe, and their present design seems comparatively free from breakage. The A. O. Smith company on their heavy gas trucks have used cast steel wheels since 1911. The same is true of the Locomobile company on their well-known trucks.

From time to time trucks have been imported from abroad equipped with steel wheels, notably the Orion, Bussing, Gaggenau, etc. However, the best known European trucks coming into this country are equipped with wood wheels, notably the DeDion and Saurer. I wish to acknowledge my indebtedness to Mr. Charles E. Stone, member of this Society, for his assistance in compiling the above facts.

## CURRENT PRACTICE

It will be noted that comparatively few well-known truck builders in this country are at present using metal wheels and those who are using them have not previously used wooden wheels.

There is one notable exception, however, the Pierce-Arrow Motor Car Company, on some of whose trucks I have recently seen cast steel wheels, although since the introduction of the Pierce 5-ton truck on the market wooden wheels have been standard. It is hoped the engineers of that company will give us the benefit of their experience and their reasons for making this change.

The vast majority of motor truck manufacturers, including those whose product dates back to the beginning of the motor truck industry in this country, have used wooden wheels consistently, improving their design from time to time, but not abandoning a material for wheel construction which has on the whole proved entirely satisfactory.

Through the courtesy of Mr. George R. Wadsworth, member of this Society, I have been furnished with reports on the mileage and condition of the wood wheels on a large group of gas trucks of 3-, 4- and 5-ton capacity, which show that in some cases the mileage covered approaches closely to 70,000. On the assumption that the tire mileage secured on these trucks is 10,000 miles per tire, this would mean that some of the wheels have been subjected to six tire changes. The report states, regarding these wheels, that "they were all in first-class condition and not a moment's inconvenience or delay has been caused by them and there is not the slightest indication of trouble in the near future." These wheels, it is scarcely necessary to say, are of modern design, are accurately constructed of suitable material, and are carefully inspected for conformation to the accepted S. A. E. motor truck wheels standards. The contention that wood wheels get out of round and present difficulties in tire application does not seem to be substantiated in this case.

As pointed out in papers on wood wheels, presented by Mr. Bert Morley and Mr. C. B. Hayes at the January, 1912, meeting of this Society, there is no question as to the adequacy of the supply of wood for wheel manufacture. The experience of many of our members with wood wheels on motor trucks, extending over periods of years, indicates that the truck manufacturers in this country are not being forced by necessity to adopt metal wheels, so that if the truck manufacturer who has been using wood

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wheels satisfactorily for many years is to be influenced to adopt a metal wheel, it is essential that he should be shown that some practical advantage would be gained by the change.

When this Society visited our British fellow engineers, several members of the American party made inquiries regarding the service rendered by metal wheels, in both England and France, and the results of the investigation were set forth in a short report which I made to the Society at the January, 1912, meeting. Briefly, it was found that cast steel wheels were being used in England in a variety of forms. Also that structural steel wheels were preferred by some. Further, that the consideration of wood wheels had not been abandoned, even by those using steel wheels as a standard, and that some truck manufacturers preferred wood to metal, and used the former as standard. In France the wood wheel appeared to be the standard to the practical exclusion of metal wheels.

More recently Mr. L. C. Freeman, a member of this Society, submitted a paper on "Tendency of Foreign Motor Truck Design" at the January, 1913, meeting in which he made the following statement: "While cast steel wheels seem to give very good results under certain conditions, they do not appear to be a universal panacea for all wheel troubles. One user who has operated a great many trucks of many different makes said that cast steel wheels were all right until the tires wore thin. In this statement I think there is food for a great deal of thought. A built-up wheel of structural steel was giving him excellent service and almost no trouble." Doubtless some of our British fellow engineers present at this meeting can supply us with up-to-date information on the status of the metal and wood wheel in Great Britain.

### CLAIMS FOR THE METAL WHEEL

At the present time there is undoubtedly a general effort being made by manufacturers of parts for motor trucks to add metal wheels to their product; and with the exception of one manufacturer, who proposes to build wheels of malleable iron, all of them are building their wheels of cast steel.

What, then, are the specific advantages offered by metal wheels which should influence a motor truck designer to specify metal construction rather than wood? The advantage must be such that it can be proved to the purchaser of the truck that he will secure an actual financial gain by the change which the engineer proposes, because to the purchaser the prime questions are the expense of operating and maintaining the truck over a period of years and the earnings or savings which the vehicle will effect. Theoretical considerations, unless borne out and proved in practice, are unavailing. Practical service conditions count with the hard-headed business man—not laboratory or experimental tests and calculations.

First, it is claimed by one of our members, who is chief engineer of a company about to place cast steel wheels on the market, that: "It is now conclusively proven that there is a distinct saving in tires on steel wheels. Some of the largest tire manufacturers guarantee as much as

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30 to 40 per cent. longer life on steel than wood." Inquiry made of the leading tire manufacturing companies, verbally or by letter, has failed to verify that statement. The opinion of several tire company officials seems to be personally in favor of metal wheels for the one reason that they are likely to be made more accurately to size, but the tire companies positively decline to guarantee an added mile or to even express the opinion that added mileage can be expected.

As to the question of accuracy of workmanship, it is entirely feasible for the wood wheel manufacturers, under the present S. A. E. Standards, equipping the wheels with S. A. E. bands, to work within the necessary tolerances and provide wheels which will have the accuracy required. Accuracy in workmanship is a question of care in construction and careful inspection and the manufacturer who insists upon accurate wood wheels conforming to S. A. E. Standards has no trouble in securing them.

Another claim made for metal wheels is that their strength is greater than wood wheels. Assuming the cast steel wheels to be free from defects, and to have the chemical and physical characteristics recommended by the Iron and Steel Division, these wheels certainly develop marvelous resistance to shocks. I witnessed a test of such a wheel recently which was subjected to the impact of a weight swung as a pendulum against the side of the felloe and the wheel was deformed beyond the semblance of a wheel and even then did not show any fracture. At the same time, as has been pointed out by the Iron and Steel Division, steel castings can not be inspected against blow-holes, and had the wheel in question contained some concealed defect, failure in testing would probably have resulted. The difficulty in securing uniform steel castings free from defects and conforming to the S. A. E. Standards is generally conceded and several of the foundries making cast steel wheels in this country, at the present time, are having difficulty in making steel castings of other motor truck parts which will pass the inspection of some of their customers. As to the strength of well constructed and properly designed wood wheels, the front wheel of a truck manufactured by one of my clients came in contact recently with a road obstruction with such impact that the strain broke the steering gear, but the wheel was uninjured, and on another truck a rear wheel was subjected to such an impact that the axle spindle was bent without injury to the wheel. Therefore, on the question of strength, that of the high-grade wood wheel is entirely adequate for commercial purposes.

The contention is also made that the metal wheel will dissipate heat more effectively than the wood wheel. There has come under my observation no case in which a truck tire on a modern motor truck has been injured by lack of heat radiation under service conditions. I assume that the heat developed in a solid rubber tire is due to the deformation of the rubber and this is greatest near the surface of the rubber which comes in contact with the ground. This surface is in contact with the air and I should expect that the heat would be radiated through the air more easily than transmitted through the base of the tire to the wheel and hence radiated by the wheel, felloe, and spokes.

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### *Cost and Weight*

The fourth point in considering the relative merits of wood and meta wheels is the comparative cost and weight. From information received from one of my clients regarding wood wheels being regularly manufactured and used on this company's trucks, and from information received from the chief engineer of one of the companies which is bringing out cast steel wheels, the following comparison of weight and cost has been made:

Set of wheels for 3-ton truck to take 36-inch by 5-inch tires, front; and 40-inch by 4-inch dual tires, rear; wood wheels equipped with S. A. E. band and Timken hubs and flanges—steel wheels having band and hubs integral—

WEIGHT

| Wood | Steel | Increase of Steel over Wood |
|---|---|---|
| Front 122 lb. each | 151 lb. | 12.4% |
| Rear 212 lb. " | 373 lb. | 76.0% |
| Set 668 lb | 1048 lb. | 57.0%—380 lb. |

COST

| | | |
|---|---|---|
| Front each $20.00 | $26.80 | 34.0% |
| Rear " 30.00 | 52.10 | 74.0% |
| Set " 100.00 | 157.80 | 57.8%—$57.80 |

Information obtained from a European manufacturer of cast steel wheels indicates that their weight is substantially the same as American cast steel wheels, but the price is 25 to 50 per cent. higher, thereby placing the steel wheel at a still further disadvantage as far as cost is concerned. Consequently, it would appear that the cast steel wheels are both costlier and heavier than the wood wheels. The burden of proof seems to rest with the metal wheel manufacturer, that they have an economic advantage over the wood wheels, resulting in a financial saving to the owner of the truck equipped with metal wheels.

### DROP FORGINGS

There is one type of metal wheel which might overcome the disadvantage, real or fancied, of the wood wheel, and which would at the same time eliminate the element of risk always existent in a casting, and also the criticism of the built-up structural steel wheel, the loosening rivets. This is the drop forged wheel. Drop forgings of high-grade steel, which after suitable heat treatments, develop extraordinary physical characteristics, would, in my opinion, be an ideal construction, unless their first cost proved prohibitive. I hope we may hear something from the drop forging experts among our membership in regard to the feasibility of such a construction for motor truck wheels.

As stated at the outset of this paper, its purpose is to stimulate discussion and secure additional data, by which the motor truck designer may be benefited and assisted in his work. I trust it may accomplish its purpose.

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A. J. SLADE.—In the paper I have given a comparison of the weight and cost of steel and wood wheels. The wood wheels referred to are of the type mentioned earlier in the paper; that is, with very large flared spokes, and a large shoulder against the felloe—the type of wood wheel which is giving such satisfactory results at the present time. The wheel is a good deal heavier than many wood wheels having smaller spoke sections. There are two very wellknown makes of three-ton trucks on the market (probably two of the most prominent), the difference in the weight of whose wood wheels is about four hundred pounds. In other words, the truck with the larger wheels and heavier spokes has four hundred pounds more weight in the wheels than that of the other manufacturer.

The figures on the cast steel wheels were given to me by one of our members, the chief engineer of a manufacturer who has designed cast steel wheels for the American market. Information as to weights of cast steel wheels produced by a foreign manufacturer for the American market conforms very closely. In other words, the weights given represent practically the heaviest type of steel wheel and the heaviest type of wood wheel, so that I think the comparison is fair.

Now the discussion on this paper really started yesterday when we heard about the wheels Mr. Browne referred to on the gas buses, which are considerably lighter than the wheels mentioned in this paper; and also when Mr. Clarkson described his very interesting structural wheels. There have also been a number of communications from members who were not able to be present which the Secretary has. Possibly Mr. Clarkson can abstract a few of those communications and then let them all go into the Transactions to be printed later.

### *Written Contributed Discussion*

By H. D. Church*

For some time past the writer has been conducting service tests with various designs of cast steel wheels on three-ton trucks, and believes that this kind of testing is the only sure way to obtain the answer whether any design of steel wheel will prove satisfactory. Pendulum and laboratory tests are, of course, valuable in obtaining comparisons of the breaking strength and shock resistance of metal and wood wheels, but my experience so far indicates that the trouble with steel wheels has come from the incessant pounding, with a load, over rough paved streets, particularly when the tires are practically worn down.

My experiments have been confined to cast steel wheels with uneven cross-section spokes, the spokes being both straight and Y, and with plain flat rims. With the straight-spoke design service breakage always occurs at the smallest section of the spoke near the rim, and with the Y-section at either the junction of the spoke with the rim or the point where the spoke separates into Y form. Castings which have been examined at the breakage point have not shown defects or blow-holes. It is my theory that the breakage is caused, first, by initial stresses set up when the castings

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cool, due to the spokes contracting radially, and the rim circumferentially; second, constant road vibration. These designs of wheels would be more durable if the rims were fitted with a cast steel re-entrant flange on either side, distributing the road shocks over a greater length of rim surface, instead of localizing them on one or two spokes.

One point ought to be discussed in connection with the design of cast steel wheels, the number of bolts used by the different tire manufacturers for fastening tire flanges. The present S. A. E. standard calls for either 8, 12, or 24 bolts on a 36" wheel. It seems that it ought to be possible to decide on a given number of bolts for a certain wheel-diameter and adhere to it, instead of giving three different numbers, which makes it difficult to obtain proper spacings so that flange bolt-holes do not interfere with spokes.

I have also done some experimenting with cast steel wheels with hollow spokes and flat rims, and with U-section spokes and flat rims, the open side of the spoke U being toward the center of the truck. Neither of these two latter designs, however, has been tested far enough to give any idea of its possibilities.

As Mr. Slade says, the burden of proof that steel wheels have economic advantages over wood wheels, rests with the metal wheel manufacturer. At the present time cast steel wheels weigh more and cost more than wood wheels. My experience to date indicates that the steel wheels will not stand up in service, and give the mileage that wood wheels will. At the present time wood wheels are satisfactory in service, and until such time as suitable wood for wheels is difficult to obtain, or the steel wheel shows as much or more durability for the same cost, I believe that steel wheels will not have extended use. There is still a great deal of experimental and development work to be done in order to find what design of metal wheel will give the best results at the lowest cost. Some form of metal wheel for motor truck service will eventually supersede wood. The ultimate type of wheel will be found only by hearty coöperation between the foundrymen and the engineers.

By A. W. Robinson*

Mr. Slade in his very interesting paper lays stress on the fact that practical service conditions count. Accordingly, while the majority of the members are probably familiar with it, the experience of the London General Omnibus Company in using both wood and steel wheels under the same conditions is of interest. This company is the largest user of motor-driven vehicles in the world. In December, 1912, we wrote saying that we had been advised that they were using steel wheels exclusively on two thousand buses, and would shortly have five thousand buses equipped with steel wheels. Under date of December 28, 1912, Mr. W. J. Iden, Chief Engineer, replied as follows:

Your statement is perfectly correct. We have steel wheels on over 2,000 buses and at the present moment are not making any more wood wheels.

Following is an extract from Le Poids Lourd, issue of March 14th: .

*Sales manager, Truck Department, Locomobile Company of America, Bridgeport, Conn.

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In its new regulations for subsidized motor trucks, which go into effect April 1, 1913, the German government has made it obligatory to have these trucks equipped with cast steel wheels.

The Locomobile Company, before putting its 5-ton model on the market, gave it an especially severe breakdown test, operating with a heavy overload and at a high rate of speed. The wooden wheels, with which the truck was first equipped, gave trouble, especially the rear. Therefore, it was decided to look into the question of steel wheels. Since then steel wheels have been made standard equipment. So far there have been no failures.

The wheel used is cast steel, solid spokes, star section, the weight being less than the weight of the wood wheel formerly used. They are considerably lighter in proportion to the size of tire used, than the steel wheels referred to in Mr. Slade's paper, viz., the weight of a steel rear wheel to take 40 x 4 dual tires is given as 373 pounds, whereas the rear cast steel wheel on the Locomobile truck designed to take 40 x 6 dual tires weighs 342 pounds.

While not able to give exact data, we believe the steel wheel increases tire mileage. It remains in a true circle, whereas the wood wheel may flatten slightly at one or more points, with resultant pounding of the tire. The steel wheel also tends to keep the tire cool.

It has been claimed that wood wheels are better than metal wheels from being more resilient. There may be something in this on metal tires, but when rubber tires are used I believe it amounts to nothing practically. Certainly, for the Polack type of tire, with the solid metal base, it would seem of the greatest importance that the felloe of the wheel supporting this base remain in a true circle.

By H. W. Alden*

Mr. Slade's paper hits the nail pretty closely on the head. The ultimate wheel will be the one which will give the best allround results at the least cost in dollars and cents, based not only on the life of the wheel itself but the life of the tire and the other parts of the truck. It is altogether too early to predict which of the two styles of wheels is going to predominate. For certain classes of service, however, in certain localities, such as the dry arid climate of portions of the West, it has been demonstrated that the wood wheel will not stand up; therefore, in these places some form of metal wheel is sure to be standard. In other localities, where the wood wheel is not subjected to climatic difficulties, there is no indication at the present time that the metal wheel is going to supersede the wood wheel.

I have very little experience to offer, but have been informed reliably that in the East there is a good-sized fleet of trucks which have been operating for several years with cast iron wheels equipped with rubber tires. A five-ton truck equipped with cast iron wheels and rubber tires has been in service in the California mountains for several years. This being the case, it would not seem that it is necessary to go to such an expensive material as cast steel for a serviceable wheel.

It is a wellknown fact that a tubular construction is in most all cases

*Chief engineer, Timken-Detroit Axle Company, Detroit, Michigan.

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the strongest which can be made. A tubular form of spoke together with a hollow box for a rim is the strongest which can possibly be put up. The company which I represent has been doing some experimental work on malleable iron wheels. Our experience so far is very limited but enough to show that the malleable iron wheel is certainly vastly stronger than the wood wheel; and when made in the tubular form with the hollow box rim, certainly strong enough to break down any other part of the vehicle. A tubular spoke with hollow box rim is certainly the best-looking metal wheel that can be put up. Furthermore, the hollow box rim makes it a very simple matter to attach the standard S. A. E. tires as the flange bolts can go directly through it.

Malleable iron is not held in the highest repute. At the same time it is the unseen defects in a casting of any kind which cause ultimate trouble, and it is unquestionably possible to get a sounder casting in malleable iron than in steel. In view of the fact that in a hollow-spoke wheel made of malleable iron, none of the malleabilized skin has been removed, the wheel has a maximum strength obtainable with malleable iron. We know from experience that malleable iron is an excellent material to withstand shocks and vibration. If this were not so, it could not be used so extensively in wheel hubs as it is today.

It would seem that the final solution of this matter depends more upon the effect of the wheel on the rest of the car than on the performance of the wheel itself. If the metal wheel is going to be so rigid, especially when the tire is worn down thin, that vibratory strain will cause trouble in axles, springs, spring-hangers, etc., the metal wheel will not come into extensive use. There is not yet enough information, from truck operation on the very poor American city streets and country roads, to throw a great deal of light on the subject.

The burden of proof today is all on the metal wheel. If a metal wheel must be used, it seems to me that a hollow-spoke hollow-box-rim wheel will be the ultimate type, and that in view of difficulty in getting perfectly sound steel castings, the malleable wheel has a first-class chance of winning out on this score as well as on the score of expense.

I know that hollow-box-rimmed, hollow-spoke malleable iron wheels can be made to weigh not more and probably somewhat less than corresponding wood wheels. Malleable iron wheels can be produced for as low a figure as the wood wheel with the steel band. On this point I have definite data.

By Frank W. Trabold.*

In reference to the suggestion that possibly a satisfactory wheel of high quality could be produced by the drop forging process, I would say that I believe there is not any equipment existing that could handle work of this size and style profitably or efficiently. Even if equipment of sufficient capacity were designed, I doubt whether the product would compare favorably with that made possible by hydraulic or pressed forgings. There are great possibilities for wheel construction along these latter lines. The necessary work in drop forging the parts would be so great and

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expensive in comparison with the pressed forgings or hydraulic forged parts that I am sure it would preclude the use of drop forgings. By the drop forging process we can get higher physical properties than are obtainable in the pressed forging work, but I understand that in this case it is not a matter of high physical properties inasmuch as the steel and iron castings have evidently given good satisfaction, but their use is condemned by reason of all castings being somewhat hazardous in that defects in the way of gas- or blow-holes cannot be noticed except in the case of failures which they cause. I cannot conceive of any one considering favorably the use of any cast product in these parts for just this reason. These defects are, of course, impossible in forgings, either dropped or pressed, as the formation is absolutely solid, and therefore so far as the hazard accompanying the use of castings is concerned, fool-proof.

The distinction between the drop forging and the pressed forging is this: In the case of the former the part is made with a drop hammer, the impact of the same requiring very heavy dies and calling for high-grade expensive labor. In the latter process the same steel is used, heated as in the drop forging process, but instead of being formed by the blows of the drop-hammer is formed in the dies by hydraulic or other pressure. The dies used in this process need not be so heavy and their life is longer, and the price of labor necessary for this process is considerably less.

By Benjamin Jerome.*

Reference has been made by Mr. Slade to a few companies who have at different times manufactured structural steel wheels for motor trucks. Among these are: The Indestructible wheel which was tried out by a half dozen concerns, for periods ranging up to two years; the wheels manufactured by the Gibbs Company for their 5-ton trucks which were reported to be satisfactory; the Couple-Gear wheel which has been manufactured since January of 1905 and is used exclusively on all trucks manufactured by the Couple-Gear Freight-Wheel Company. He has neglected to mention, however, the Walker Balance-Gear Company, of Chicago, who use structural steel wheels on all their models ranging up to 5-ton capacity, with results which I understand are satisfactory.

Out of these four named structural steel wheels one only is reported as unsatisfactory, and then after two years' service. Since the Gibbs Engineering Company is no longer in existence we have left the Walker Balance-Gear Company and the Couple-Gear Company using the structural steel wheel exclusively and with satisfactory results. I will set forth a few points gained from their seven years' experience with structural steel wheels.

Owing to the fact that the Couple-Gear principle of drive embodies an electric motor enclosed in each wheel, there were certain requisites for its successful operation, chief among which were a water- and dust-proof housing, motor accessibility and a wheel of extreme rigidity. These requirements were the determining factors in the selection of the structural type of wheel. This particular wheel consists essentially of a tire

*Engineer, Couple-Gear Freight-Wheel Company, Grand Rapids, Michigan.

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band and two steel disks. The disks are made a press fit into the band, being held firmly by bolts against a shoulder. The disk proper is of pressed steel, with sufficient dish to give motor-clearance and stiffness. At the center is riveted a cast steel hub, while at the periphery a forged steel ring is riveted to either side of the disk, to give added bearing surface and allow stock for machining.

With the exception of a few minor details, such as tire fastening methods and the like, there has been no change in the original design, and today wheels of this type are being manufactured with tire bands conforming to the S. A. E. motor truck wheel standard.

In referring to one make of structural steel wheel, Mr. Slade said: "The severe strains and shocks due to irregular road surfaces are reported to have loosened the rivets holding various members together, and the wheels were not found to be permanently satisfactory."

I must take exception to this statement as applying to all makes of structural steel wheels. Recently I had occasion to thoroughly inspect a set of Couple-Gear wheels that had been in service for more than five years. There was not a single case of a loosened rivet; in fact, the wheels were just as good as new, with the exception of the brake-drums being worn. This case is not exceptional either. These wheels outwear the rest of the truck. To show the varied service to which they are put, we use them on commercial trucks and on heavy fire apparatus up to six-ton capacity, with running speeds as high as 30 m.p.h. About a year ago we were called upon to rebuild one of our trucks that had been in a fire. All wooden parts were burned off and the tires ruined, but the wheels were unharmed. It is needless to say what would have happened to wood wheels in this case.

Steel wheels cannot get out of round due to shrinkage or warping of wheel stock and thereby produce difficulties in tire application. In fact they do not change shape even after years of service. This is proved by testing wheels that have been in service a long time, as well as by the fact that they must retain their original shape in order that the gear conditions in our wheels shall not change. It seems next to impossible to get into a wreck that will not smash the truck rather than damage the wheels. I was in a collision in which the curb and a telephone pole were struck by the front wheel with sufficient force to buckle the truck frame, bend the spring bracket and put the steering gear out of commission. No damage was done to the wheel. No wood wheel could go through a similar accident and come out unharmed.

No comparative data as to tire wear on steel and wood wheels seem to have been offered. In this connection, however, I would say that the tire manufacturers are willing to give us their maximum guarantee, 10,000 miles. This seems in favor of steel wheels, for in our particular case there is the heat due to an enclosed motor to be radiated, in addition to that generated by the tire itself.

The fact that steel wheels can be made that (1) do not change shape, (2) are not hard on tires, (3) will not loosen up in service, (4) give extreme rigidity, and (5) are practically indestructible, leads me to believe

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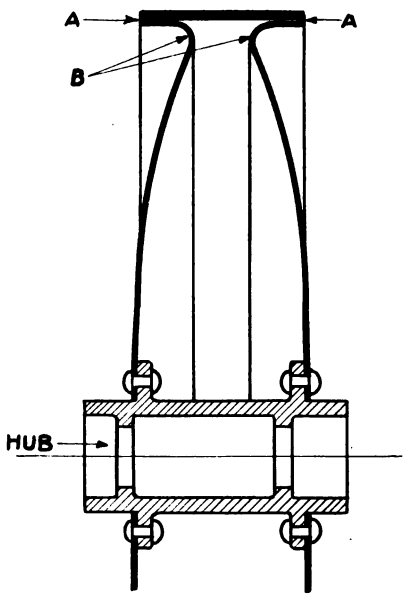
that they are better for long life and hard service. For this kind of work first cost is not the governing item. Further, it appears that the structural steel wheel is not subject to the one criticism of the cast steel wheel, liability of blow-holes.

By R. L. Morgan.*

Two types of disk wheels were produced by the Morgan Motor Truck Company, one of ⅛" and the other of ¼" side-plates. The difficulty with the lighter wheels was that the plates cracked at the point marked *B* in the sketch. The ¼" plate wheels held up splendidly; a large number of these wheels have been operated for about five years. The reason for abandoning this type of wheel was not failure of construction, but the high cost of autogenous welding which had to be done at point *A* in order to fasten the rim to the side plates; on a 36" wheel this meant about 18 ft. of linear welding. We decided it was much cheaper to use a cast wheel, the great percentage of which we made out of ordinary cast iron.




I have made this statement to several people. It surprised them somewhat, but the proof of the pudding is in the eating. I know of only one of these wheels that has given away, out of some twenty-five trucks.

By Bert Morley.†

In our opinion it is just as easy as ever to get wood material for truck wheels. The wheel manufacturer should have at least a year in order to secure the proper material and properly prepare it. We have noted many of the failures in truck wheels. In most cases they can be readily traced to improper quality of material. In some cases the wheel manufacturer has not had sufficient time to season the wood.

The services required of the wheel on a slow-moving vehicle are entirely different from those on a pleasure-car wheel, as they have not the protection of the pneumatic tire.

*Consulting engineer, Worcester, Massachusetts.
†Sales Manager, Kelsey Wheel Company, Detroit, Michigan.

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By Phineas Jones.*

Of course, we believe in a wood wheel. We do a great deal of repairing on all kinds of wheels, both pleasure and commercial car, and are in a position to see all the faults of the different makes.

We have found that the principal defects of the commercial car wood wheel are due to

1st—Faulty workmanship.

2nd—Faulty design.

Under the head of faulty workmanship we find two troubles:

1st—That the material is not properly dried.

2nd—That the S. A. E. Bands are not shrunk on correctly.

Both of these faults can be obviated by any good wheel-maker.

Under the head of faulty design, we find that there are not sufficient spokes in the wheel. This lies principally with the car designer, and if left to the wheel-maker we believe would be overcome.

We use the following table:

| *Wood Wheel Diameters* | *Spokes* |
|---|---|
| 42, 44, 46 and 48 | 18 |
| 36, 38 and 40 | 16 |
| 30, 32 and 34 | 14 |
| 24, 26 and 28 | 12 |

By W. E. Farrell.

I would like to refer to some features in which the cast steel wheel is superior to the wood wheel. Cast steel wheels are furnished round to begin with, and remain so in service. On page 128, 1913 Transactions, S. A. E., Part I, appears the following statement:

> "If you will caliper any wooden wheel after a set of tires has been worn out, you will find the wheels are from one-eighth to one-quarter of an inch out of round."

Cast steel wheels can be made with a tolerance of only .01 of an inch.

Cast steel wheels do not possess the following objectionable features of wood wheels:

1. Effect of temperature and other climatic conditions.
2. Weakness when subjected to side stress.
3. Not reaching the truck manufacturer in one piece complete in itself.
4. In the case of dual tires, non-support by the spokes of the outside of the wheel.

A company using fifteen or more trucks with cast steel wheels writes stating that the spokes in wooden wheels wear into the sockets and have to be renewed or the wheels rebuilt. Their letter concludes: "We would not purchase a truck that did not have steel wheels."

Mr. Slade lays great stress upon the possibility of hidden defects in steel wheels, but their strength is so much greater than the requirements demand that any argument based upon such a possibility is of no moment. The cast steel wheel which Mr. Slade refers to in his article as having

*Treasurer, Phineas-Jones & Company, Newark, New Jersey.

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been "deformed beyond the semblance of a wheel," and which he states would probably have failed in testing had it contained some hidden defect, was a defective wheel, and for that reason used in making the test referred to.

The comparison drawn by Mr. Slade between the cost of wood and cast steel wheels is unjust to the latter.

The total weight he gives of the four cast steel wheels for a 3-ton truck is 1,048 lbs., whereas the total weight of the four cast steel wheels for a well-known 5-ton truck is only 840 lbs. The manufacturer of this truck writes that the corresponding weight of wood wheels, in exactly the same condition of equipment and finish as the cast steel wheels, totals 972 lbs., a difference in favor of the cast steel wheel of 132 lbs. per set.

Satisfactory cast steel wheels can be made when the specifications and the design are not entirely controlled by the engineer or the purchaser, to the exclusion of the foundry.

By A. M. Laycock.*

Mr. Slade states that the best known European trucks that come into this country are equipped with wood wheels, notably the De Dion and Saurer. I beg leave to differ with Mr. Slade, as the English Daimler buses on Fifth Avenue have steel wheels.

Mr. Slade quotes a statement that one user who had operated a great many trucks of many different makes said that cast steel wheels were all right until the tires wore thin. We have made experiments, the last of which was brutal in the extreme, to prove the fallacy of this claim. Taking a one-ton truck, which was capable of 30 miles an hour, and loading it up with 2,500 pounds, the rear tires being 38 in. by 4 in., the tire already being worn down to 2 in. thick, we cut out a piece 18 in. long down to the solid metal base. We ran this for about 1,200 miles until the police authorities stopped us on account of ripping up the road. We sent our hardest testers out with instructions to break this wheel if possible, and up to the time of the police stopping us it was impossible for them to even deform the wheel.

Mr. Slade mentions that one of the members—who happens to be I—makes the following claim: "It is now conclusively proved that there is a distinct saving in tires on steel wheels. Some of the largest tire manufacturers guarantee as much as 30 to 40 per cent. longer life on steel than wood." I first obtained this information from the purchasing agent of one of our largest tire users. Not being satisfied with what he told me, I asked where he had obtained the information. The source was given to me, and I wrote as follows:

Dec. 23, 1912.

> "We have just received the enclosed letter in response to our inquiry as to whether you guarantee a greater mileage on steel than wood wheels. It has been reported that you held out for as much as 30 per cent. longer life on steel than wood wheels. The writer would very much appreciate an expression from you as to whether this is so or not."

*City Engineer, Axle Department, Sheldon Axle Company, Wilkesbarre, Pa.

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In reply to this letter we received the following letter dated Dec. 26, 1912:

"We are in receipt of your letter of the 23d, enclosing copy of letter from Mr. —— regarding steel wheels. Our first experience with solid metal wheels was with the Morgan Motor Truck Co., who have used, as an exclusive equipment on all their trucks for the past three years, solid cast wheels and wireless tires. In all this time but one of their 5-ton trucks has required adjustment on these tires. This is a most remarkable condition, and we are quite ready to divide the glory with the wheels. With the White Co. we have had similar experience, and believe that the *percentage that you state* is not far from being correct in the mileage obtained from tires used on metal wheels.

"There are a number of reasons for the success and greater mileage of tires used under such conditions, the principal one being an absolute round wheel which gives a perfect fit and setting for the tire in every part, and also a true and free-rolling motion. Another is on account of the ability of such a wheel to radiate heat, heat being a great factor in the early failure of solid tires as well as pneumatics. We hope that the information given you may be of assistance."

Prior to this the writer had written Mr. Walter J. Iden, chief engineer of the London General Omnibus Company, regarding the same question. In response, Mr. Iden wrote as follows:

"We, of course, have used a tremendous number of both steel and wood wheels, and as a standard we now adopt a steel wheel which gives us less trouble. Wood wheels creak, and if not made well and of proper timber soon require attention.

"With reference to tires, this depends very much on the road over which they run and the quality of the rubber supplied, and may vary between ten and twenty thousand miles for back tires; we have one exceptional case where front tires have run approximately 50,000 miles. This, of course, is very exceptional indeed, and I should say that 25,000 miles would create an average.

"I am not giving you the names of these tires, nor anything else, because you may inadvertently mention the matter to some one and possibly they would create an advertisement of it."

Mr. Slade states "there has come under my observation no case in which a truck tire on a modern motor truck has been injured by lack of heat radiation under service conditions." I have before me a letter from the city of New York fire department in regard to the test of two motor-propelled, high-pressure hose wagons.

"Weight of trucks, 9,575 lbs. each, carrying 6,000 lbs. additional. Route to Coney Island and return, a distance of about 38 miles. Start made from Broadway and Fifty-ninth Street. A speed at times of 32 m.p.h.; 20 miles an hour maintained with ease.

"The test, in my opinion, was satisfactory. The cars meet requirements of the specifications in every particular with the excep-

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tion of the rubber tires, which were burnt off front wheels on both cars. The cars take 36 x 5 tires on front and 36 x 5 dual on rear wheels."

I was told by an eye witness that one of the tires produced a blister as large as a cocoanut. One of the men pushed his pocket-knife into it, causing an explosion which blew his cigar from his mouth. This appears to me very much like a lack of heat radiation under service conditions.

The weights and prices given by Mr. Slade are very conservative. At the present status of steel wheels it is preferable to err on the long side.

By J. Morat*

Mr. Slade's paper comes at a very opportune time. I agree with him on the subject of standardizing steel wheels as well as wood wheels. The S. A. E. standards have been made for wheels which have been brought to their high state of perfection by ages of experience. Cast steel wheels, having been in practical use in this country for only two or three years, cannot be expected to have had "a show," but the subject is coming to the notice of more people every day, each one bringing in his quota of ability and experience.

If some steel wheels have given poor results, some in service now are giving excellent results. Great strides have been made in the line recently; whenever the demand for first-class steel wheels has been backed up by coöperation between the truck engineer and the foundryman of ability, some remarkable results have been obtained.

The time is not far distant when the cast steel truck wheel, properly designed, cast and heat-treated, will be stronger and safer, for the same weight, than the wood wheel taking the same size tire. The facts and reasons are as follows:

Of the many designs of steel wheel in use, few show signs of coöperation between theory and practice. The result is that the design of the wheel is not always as light and strong, or suitable for obtaining the best that can be obtained from a steel casting, and there have been some failures or complaints of high prices. A suitable design and suitable patterns enable the steel foundry to eliminate almost entirely the preventable defects, such as cracks and blow-holes. In the present state of the art, there is hardly any more excuse for the steel foundry producing steel castings not free from cracks or blow-holes, than there is for the wood wheel manufacturer to use defective wood. Unavoidable defects such as small sand-holes will have to be figured on, of course, but small defects are encountered in wood also. As to the effect of the small sand-holes on the strength of the castings, I have ascertained that upon annealed castings similar in section to the spokes used on steel wheels, the elastic limit and tensile strength come down less than 10 per cent. and in most cases less than 5 per cent. In some cases, when the defects are in compression, there is no difference at all between the absolutely perfect casting and the one that has very small sand-holes. Now if it is figured that one

*Engineer, I. G. Johnson & Company, Spuyten Duyvil, New York.

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side of the wheel is submitted mostly to tension, it is easy to locate that side of the wheel in the side of the mold that will secure a perfect casting, that is, in the nowel or drag. So that the defects mentioned in Mr. Slade's paper need not cause any worry if the castings are made by a foundryman who understands his business.

A number of steel wheels have not been annealed or heat treated before being put into use, and broken in service when the loads put upon them did not strain the metal above 15,000 lbs., whereas other wheels have withstood the test with loads, similarly calculated, of nearly double that amount. If the spokes of the wheels that fail are sawed off it will be found that the saw cut will open up. I have seen cases where the gap was 3/32 in., showing that without load the spokes were under a state of tension much above what they would be in the hardest kind of service. If the steel wheel comes out of the foundry without any internal strains or with such low internal strains as will help the design, the best wheel will be obtained. In this case the parts of the wheel can be figured on to stand from 100,000 to 120,000 lbs. per sq. inch ultimate load in bending, the metal being still soft enough to stand a lot of deformation before breaking. This is not based upon theory, but upon numerous practical testing machine tests of castings.

Figuring that steel weighs about nine times as much as hickory, even if the relative strength between the materials be only nine-to-one, the steel wheel properly constructed has the advantage of having hub, spokes and rim all in one piece. In dry and changeable climates or where the wood wheel is overloaded, play develops between the spokes and felloe.

In reference to the relative weight and cost of wood and steel wheels, the examples given by Mr. Slade apply to a heavily built steel wheel. It would be interesting to find the relative amount of punishment or load those wheels are actually capable of carrying. I have had submitted to me cases where the real wheel loads on a well-known make of a three-ton truck were nearly as high as those on another make of a five-ton truck. For trucks of less than two-ton capacity, I believe wood wheels can be made lighter than the steel wheel, on account of the difficulty of casting very thin sections in steel. Nevertheless, we have made several hundred successful steel wheels of one- or one and one-half ton capacity. I think it is possible to build a steel wheel of three-ton capacity of about the same weight as a wood wheel that will give as good service, but if it is remembered that the tire designs and the S. A. E. standard methods of attachment have been made to suit the wood wheels and that the steel wheels have had to be designed to adapt themselves to those conditions, it is safe to predict that the steel wheel could be modified so as to enable the weight to be reduced materially.

All that the steel wheel designers and manufacturers require is a little time to observe the practical results of their wheels in service and coöperation with the truck engineer.

## DISCUSSION.

L. S. Bowers.—Mr. President and gentlemen: I have been very much interested in Mr. Slade's paper, as well as in the letters from the several engi-

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neers, because it expresses the viewpoint of the automobile engineer, who, it seems to me, would be prejudiced instinctively in favor of metal working over wood. There are a number of factors to be considered in making a comparative examination of the relative worth of the metal and the wood wheel. In the first place, I do not want to dwell on this, but I think, because of our own peculiar position in this country, it is unfair and improper to consider the relative tests made by our British friends. We know that their facilities, the character of timber that they have, their methods of manufacture and their study of wood wheel manufacture have not progressed as ours have. So that they are in a very different position in making their comparative studies. In this country I do not think very much effort has been made in the matter of this comparison.

The first question, that of the possible and proved durability, the endurance of the wheels, is, of course, a vital one. We have to stop a moment and consider that the manufacture of wood wheels in this country is really a new industry. We started out, we who are wood-wheel-makers, following the precedents of the wagon-wheel manufacturer. Experience was extensive in the manufacture of wagon wheels, limited necessarily in the making of wheels for heavy motor vehicles. We have had to work to meet variously changed conditions, and have developed a character of manufacture which is very different from what it was a few years ago. We are meeting new conditions which have developed and are coming to a point where we are making a much stronger and more solid and compact construction, effecting methods of manufacture which assure trueness, particularly the round, which insures greater life of the tire. One of the objections which have been made in the past against the wood wheel has been the inability to make it perfectly round. That objection we have overcome. We have been able to follow in line with the suggestions of the S. A. E. Standard Wheel Dimensions, although originally we thought we could not fully meet those requirements.

So far as the timber available in this country is concerned we now have assurance of supply sufficient to accommodate all the requirements for many years to come. We have opened up big sources of timber supply; there is no possible fear of shortage for a long period.

A point of very vital consideration that seems to have been passed over, but a point touching the value and security of the wooden construction, is the effect on other structural parts of the truck. Now, we know, all of us, that wood is an absorber of shock and of vibration. Steel is a transmitter. When we have a new rubber tire, not very much worn, we assume that it is going to take up a great deal of shock and vibration. When that tire begins to wear it is not sufficient to take up enough of the vibration and shock, and the dangerous elements are bound to be transmitted and carried into the axle and other structural parts of the car, unless dissipated by some intervening factor. In wood we have an absorber which will take up the greater part of the vibration and road shock passed through from the tire.

W. E. FARRELL.—I want to take exception to Mr. Slade's efforts to have cast steel wheels classified with some other steel castings which he

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says the S. A. E. has gone on record as stating are only to be used at great risk. There is nothing in the manufacture of cast steel wheels which would warrant such a classification. They are among the easiest steel castings to make successfully and perfectly in a properly managed foundry. We firmly believe that with the conjunction of a steel foundry knowing how to make cast steel wheels and a machine shop properly equipped for handling same, cast steel wheels can be manufactured in similar quantities in competition with wood wheels.

J. E. HALE.—From the tiremaker's standpoint I would like to say that in spite of the benefits which have accrued from the inauguration of the S. A. E. truck wheel dimensions and tolerances, we still have a very considerable amount of trouble in tire applications due to lack of respect for the prescribed tolerances. We find the most troublesome offence in the wheels which are out of round and especially those in which the deviation from true round is localized at one place; a flat is the result. Metal base tires, either demountable or pressed-on, always give trouble on such wheels. Inasmuch as steel wheels are made to very accurate dimensions and moreover will retain their original size and shape, you can readily see that the tire people are anxious for the development of metal wheels.

A well-built wood wheel is pretty rigid and a properly designed steel wheel will be fully as flexible as a properly designed wood wheel.

I have been following the steel wheel development pretty closely and find that some of the steel wheel manufacturers are not making their wheels complete S. A. E. standard. They make the outside diameter, the width of the wheel, properly, but leave out the possibility of bolting on flanges which some types of tire demand. That is not fair because the consumer who is using a car equipped with wheels only partially S. A. E. and wants to change to some tires which take side flanges, cannot do so because there is no provision. Everybody should bear that in mind in considering steel wheels. It is only fair to the consumer.

THOMAS CLARKSON.—I would like to say how much I appreciated reading Mr. Slade's paper. It appears to my mind a level-headed paper, particularly the comparison and statement of the situation between wood and metal wheels. His figures as regards weight and cost appear rather excessive. The weight of a set of wood wheels for a three-ton truck is given as 668 pounds, which is considerable more than the weight of a set of cast steel wheels used on the London General bus referred to by Mr. Browne. I believe the net weight of a set of the London General Omnibus Company's cast steel wheels is 610 pounds. That is about 450 pounds less per set than the figures given in Mr. Slade's paper as the weight of a set of cast steel wheels. Mr. Slade tells me that our European practice in the matter of steel wheel construction has been rather extended over here, in view of the heavier demands it was anticipated the roads would make upon them. But with the forged steel wheel, to which I referred in a previous discussion in this meeting, we have been able to make a set of wheels for a three-ton truck, weighing only 440 pounds, and to the present they have stood up remarkably well. That seems a very extraordinary reduction in weight from that given in Mr. Slade's paper.

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We all recognize that the first cost is not the principal thing. Tire maintenance may wipe that out very soon. In the matter of first cost a set of built-up forged steel wheels need not cost more than $30 above the figure given by Mr. Slade as the cost of a set of wood wheels.

Respecting the number of bolts for tire-retaining flanges, we have found eight quite a suitable number, better than a larger number, because of shortening of the time of changing tires. We find that it is better to place those bolts near the spokes. In this way the strength of the rib or flange is not weakened between the spokes. That rib or flange is required to stiffen up the girder, so to speak, between the outer end of two contiguous spokes. Our practice with wood wheels was to increase gradually the quantity of wood, the surface in contact in the hub, making the wedge and diameter around the hub larger; because we found the wood wheels would get loose there, starting creeping. Another difficulty was as regards the outer ends of the spokes. They needed more bearing surface, so the spoke was widened out and made to take practically the full width, instead of occupying about half the width of the felloe. Even so they will not stand two years (60,000 miles) of London bus work. I believe the reason is largely due to not only the stress, but to the variation in humidity. It has been mentioned by one of the correspondents how the arid climate tells adversely on wood wheels. We have noticed that in dry weather the wheels will start getting loose and begin to crack. We have tried keeping the hose on during the night after coming into garage, but even then the wheels will not keep tight.

JOHN R. CAUTLEY.—Passing by the historical portion of Mr. Slade's paper, which is not of prime importance at the present time, I beg to take serious exception to a number of statements made in the remainder of the paper. It is quite true that few truck makers in this country have in the past used metal wheels, but compared with European practice the truck is very young in this country; and although road conditions are more severe here, the life of the wheels in quantity has probably not been studied quite so thoroughly. In any case, it is certain that mileage of 70,000 for wood wheels is unusually good, as I know of complaints from truck users in the East as well as in the arid regions of the country. Although it has been stated repeatedly that the failure of wood wheels in the London bus service is not a criterion, I think that the severity of this service is much underrated, as these buses are on the road continuously for long periods of the day, with such short stoppages that they cannot have any periods of rest in which to cool down and adjust themselves, as is the case with most other commercial vehicles. In fact, I am sure it will be found in similar service in this country that the wood wheels will fail in spite of the better quality of wood.

Mr. Slade states that the wood wheels had not gone out in England in 1912 and that structural wheels are still in use. I understand that the situation now is that wood wheels are being used less and less all the time and that structural wheels did not prove a success. It might

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further be mentioned that in France *all* the vehicles which are subsidized by the French Army are equipped with steel wheels and most of them with the wheels of a certain make, especially in the heavier trucks.

Referring to the statement that there is no difference in tire life when using steel wheels, I have authentic proof that with properly designed steel wheels there is an increased tire life. However, the people who make tires do not wish to be quoted, as they have no desire to get into a controversy with wood-wheel-makers. This would seem to fortify the inclination of the tire companies in favor of the steel wheel. As to accuracy of workmanship of wood wheels, this can be attained on new wheels but cannot be *maintained,* owing to the shrinkage of the wood in dry weather and swelling in wet weather. I know one large user of commercial vehicles whose practice was to turn the hose on the wood wheels every evening when the vehicles came into garage throughout the summer.

Mr. Slade is very skeptical about the reliability of steel wheels. I cannot speak for other makers, but for the maker I have the honor to represent I would say that where the metal is handled in an electric furnace and wheel-making is a specialty, reliability is attained. In fact, it is the practice of the foundry not to make spares of castings with which they have had previous experience.

It has been found by experience in bus service that rubber tires have given trouble from overheating; although the heat is generated at the contact of the tire with the road, much of it is conducted into the tire. The trouble above mentioned occurred from the soft tire becoming detached from its hard base.

In regard to increased cost and weight of steel wheels over wood, speaking from personal knowledge of the steel wheels I can give the following figures for weights of hollow-spoke hollow-rim wheels in actual service on the L. G. O. and Daimler buses and would say that in general we found that this type of wheel can be made as light as wood:

| | | |
|---|---|---|
| L. G. O. front | 36 x 4 | 77 lbs. |
| L. G. O. rear | 40 x 4 | 172 lbs. |
| Total weight | | 490 lbs. per set |
| Daimler front | 36 x 4 | 112 lbs. |
| Daimler rear | 40 x 4 | 216 lbs. |
| Total weight | | 656 lbs. per set |

The cost is undoubtedly greater, but, although Mr. Slade has made a very strong case for the wood wheel, it seems hardly borne out by the evidence at hand. The question of steel wheels in general is slightly different. The cross-section type of wheels has given trouble in service, especially when made from inferior grades of cast steel and malleable iron. These facts, together with the further fact that many European founders rushed into the business without proper facilities, gave the cross-section

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and Y-spoke type wheel something of a black eye. Furthermore, even with the best of steel made in an electric furnace, the cross-section wheel gave some little trouble. It was for this reason that the hollow-spoke plain-rim wheel was made. This wheel gave a much better support under the rim, for the rim and the bell shape of the connection between the spoke and rim allowed for a better taking up of casting strains. Finally, owing to the fine quality of electrically smelted steel and a long experience with these wheels in both the foundry and the pattern shop, it was found possible to cast a hollow-spoke hollow-rim wheel such as is now used on the London bus company and by many other European manufacturers.

The steel wheel, especially in its most highly developed form, is a case for special manufacture where the foundry must know how to design truck wheels to suit commercial practice and not violate any of the best foundry practice, and the shop use the very best of material handled by workmen expert in this particular line of work. This is what has made some steel wheels a success. Wheels made in this manner will last as long as the truck and never give any trouble in any service which the truck can stand. This I doubt if the wood-wheel-makers can even claim.

C. B. WHITTELSEY.—Mr. Chairman, in the letter of comment on Mr. Slade's paper on motor truck wheels, Mr. Church brings up the point that the number of bolts used by the different tire manufacturers for fastening the tire should be considered in connection with the design of cast wheels. As stated, the S. A. E. Standard calls for 8, 12, or 24 bolt-holes on a 36-inch wheel. This was recommended so that there would be equal spacing between the bolt holes, and different car manufacturers could all use the same spacing generally adopted by the different tire manufacturers. Some tire manufacturers require more compression than others on the side to hold the tire in position on the flange. When less compression is necessary, a lesser number of bolts is used, which lightens the equipment. In many makes of tire more compression is necessary; in these cases a greater number of bolt holes is required. That is the logic of the practice recommended.

### *Closure By Mr. Slade*

The discussion of my paper has been so extensive that I will merely make a few general comments on the same without discussing detailed points brought up by individual members.

Some of the statements by members interested in cast steel wheels are valuable in the assurance that sound wheels of this type can be made at a lower cost and weight than the figures in my paper would indicate, but I would emphasize that these figures were furnished me by our own members, some of whom are apparently unwilling to now support their own figures. We may trust that this is an indication of rapid progress in this branch of the industry, and certainly such assurances by Messrs. Far-

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rell, Morat, and Cautley will add to the confidence of the motor truck designer.

The interesting information given by Mr. Jerome and Mr. Morgan on structural wheels should also prove of value, and Mr. Alden's information regarding malleable iron wheels is especially interesting, as well as that of Mr. Trabold on the possibilities of drop or pressed forged wheels.

It is to be regretted that but few data have come to light regarding tire wear on different types of wheels, since the paper was prepared and the discussion took place. The attitude of the tire manufacturers remains unchanged, but this attitude seems to be a sound one in view of such data as are available which, while meager, indicate clearly that the material of which the wheel is constructed has less to do with tire mileage than almost any other consideration, such as speed, acceleration, weight, etc.

As to the present status of the whole situation, one-half a year after the preparation of my paper, I see no material change in the attitude of truck manufacturers and users, but it is at least interesting to note that a company having one of the most important installations in New York City has recenly imported another lot of twenty-five De Dions equipped with wooden wheels, while, however, experimenting with various types of metal wheels in the hope of eventually securing a superior construction.

I thank the members for the courteous manner in which they have discussed my paper and for the interesting and valuable information adduced.

On motion, the meeting adjourned.

COKER F. CLARKSON,
*Secretary.*

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# AN IDEAL AUTOMOBILE PLANT

*Address of Henry M. Leland at Summer Banquet of the Society, June, 1913*

TOASTMASTER HOWARD E. COFFIN—There is in this room one man who has a world's record. He can see a one-thousandth part of an inch farther than any other human being. Even the Royal Automobile Club has had to award him the Dewar trophy. I refer to Mr. H. M. Leland (applause), a man whom we all respect for his achievements, and whom we love for himself. Mr. Leland (applause).

MR. H. M. LELAND—Mr. Toastmaster, invited guests, our friends from abroad: It is a great pleasure to be here tonight and to look into your faces. I am going to give you tonight a little shop talk. You know that is something we are not allowed to do on ordinary occasions. To be old-fashioned is out of fashion, but I am going to be real old-fashioned tonight and talk to you about the shop practice, about an ideal automobile plant; not one that is located in Detroit, or perhaps anywhere at the present time. I do not know whether there is such a one, an automobile plant that might be and that I believe will be in full operation some time. I think you will all be interested in some of the things I will tell about that plant. All of you who have gone into the automobile business and are interested in it desire, of course, to make a success. Now, there are a great many different ideas of success. Some think that a man who is employing large numbers of men, and has acquired great wealth, has been successful. Not necessarily—not at all. It all depends. A man who has acquired great wealth and who is employing large numbers of men successfully, who has always played fair, who has always treated them justly and equitably, and dealt fairly with everyone, and done his duty faithfully and been a clean, straightforward, honest man, that man is a huge, grand, and a noble success (applause).

I was once asked how it was that a certain concern made such an excellent product, sold that product for such a reasonable price, and at the same time paid very handsome dividends. I answered in two words, and those two words are simply, "knowing how." Afterwards, I spent considerable time in explaining what I meant by "knowing how" (laughter).

The art of knowing how to make a good automobile for the least possible money is a great art. It is not being practiced in Detroit today (laughter and applause). The problem, the great thing that will accomplish so much when you have done all that various people have ever said in their lectures or written in their books, the main issue is left unsaid. It is so simple we do not take any notice of it. It is the thing that we learned when we were children in the old-fashioned days. I do not know whether the children will learn it now or not. In the old-fashioned days we had genuine mothers who taught us old-fashioned common sense. That old-fashioned sanctified common sense is worth more than all the scientific investigations and time studies that were ever made (applause).

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Don't worry, gentlemen, about the automobile business becoming dead—no more demand for cars—because there is nothing in that. Don't worry about your competitors. If you have anything good, take them in and show it to them and say "Go home and improve on it if you can" (applause). If everybody made good cars, there would be an immense demand for those cars. A reporter asked me out in Seattle: "How about this automobile business? Is it going to fritter away in a few days just as the bicycle business did?" I said, "Why should it fritter away? It is the greatest blessing that has ever come into the human family. Anybody who wants to go somewhere and come back again purchases an automobile. In this country there are one hundred million people and about thirty million of those people want an automobile and they want it badly."

Just as long as there are children born into the world, they will all want automobiles. There is no danger of getting too many. Competitors all help—they do a lot of advertising. If you make a really good car that advertises itself, the public are aroused to have an automobile by the other fellow's advertising and you give them the cars (laughter and applause).

How is the man who knows how going to make this ideal car—because it is going to be made? He will make it with an organization entirely different from the ones you see nowadays. He will not go down to New York, or some other scientific place, or theological seminary, and import a man to be a great infallible potentate, to sit in the center—that is the great fad now, central organization—with a line running out here to this, and out here to that, and to push the button to each of those places according to the record that he happens to be playing when he touches the button. That does not make good automobiles. Now, how are you going to make a good automobile? First of all, you have to know how. That is a great big word. Second, you are going to start making them. You are going to design an automobile that you believe will be the best that human art has ever conceived of. It is going to be made strong enough to run at the highest speeds over the roughest of roads. It needs to be made comfortable and luxurious so that our people will get into it and ride in comfort. It must have reliability, so that when you start off you are not going to have nervous dyspepsia thinking that you will never come back again. Each piece must be made of such material that it can perform its proper functions adequately and correctly. Then you must decide how you are going to make those pieces. There come in the great experience, ability, and wisdom. The manager must know what the best machinery is, and if perchance he finds after a year or two that a new machine for any given purpose has come out, that will do twice as much, or the same amount better, he cannot afford to keep the old machine; he must discard it and he will discard it. For each one of the pieces that he proposes to produce, he will buy the best machine that the world has yet produced to do the work. Having the machine installed in his plant, he will equip it with the best tools and fixtures modern art and mechanical skill can provide. Having got that far he will assign a man to the machine, and teach him how to operate it. Don't let that get away from you, because that is not the present practice. That is one of the simple things that we

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overlook. He will teach the mechanic how to operate the machine at the most rapid speed possible and maintain the accuracy he proposes to have in the particular part, in order that it may perform its function. Then he will run the machine to make the least possible number of cuts to secure the proper accuracy and get the results that he wants. He will teach the operator to make the piece precisely right according to his test tools and his means of determining when it is right before he lays it down; and having got one piece right, he will immediately make another one just like it, and he will keep making them like that.

### INSPECTION

When ten pieces, and a hundred, and a thousand, and ten thousand, have all been made precisely right, I want to ask you gentlemen, in the name of common sense, what can the inspector do to that piece? Do you not see that you have no use for the inspector when you get at the matter in that way? But that is not the method now.

### COST

The same procedure will be taken with each and every other machine. Pursuing that course and getting this particular kind of product, do you not see that our man is not going to worry about his cost department? He is not going to have a big room full of typewriters where the girls and boys are as thick as the men are in this room, trying to determine what the cost in a given department is. He does not care a tinker what the cost is. He knows that Henry Ford or any other man cannot make those pieces any more cheaply than he is making them.

The great art is in teaching the young man how to work so that when he lays a piece down it is finished. You cannot do this work with militant organized labor. It cannot be done. Militant organized labor has only one motive, to get along without work. They are not trying to see how much they can do, or how well they can do it, but how they can keep themselves on your payroll and do just as little as they can.

If you are running a factory and are going to set up a new machine, don't send over to one of the other automobile factories and get a fellow who has been running a machine there, a man who thinks he knows all about it, because the trouble with that fellow as a rule is that he does not know a blame thing about it that he ought to know. The only thing that he ought to do is to forget all that he thinks he knows. Then you should teach him to run and operate the machine correctly. Where can you get the people? Watch trains as they come into town and take the young boys from the country who have not yet been ruined by the temptations that will lure them in the city and who have not yet been spoiled by militant unionism; who want to work and get an honest living. Take these young men into your plant, give them some good advice, teach them how to do the work correctly, and tell them they will have to do it that way if they stay with you. When you have done that with one man, ten men, one hundred men, one thousand men, and ten thousand men, you will have solved the problem and you can make the best car in the world for the

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least possible money. It will be done some day. That is what I mean by "knowing how." That is about all there is of it.

I have not talked any about scientific management. I am not discouraging scientific management. I have not talked about time study. What does the time study amount to unless the man who makes it knows how? I have seen in the United States new companies which were going to revolutionize the automobile business, spend their money for machines antiquated in type and style, but new in fact, that had been discarded by other people, sold almost for scrap. What about the smart man with the spectacles who is making a time study of just what a machine is doing, that takes four hours to do an hour's work? What do you care about that kind of time study? I say it does not amount to anything. The real thing is knowing how; getting a machine that you know is up-to-date and doing the very best that can be done. That, gentlemen, is all there is of it.

## INSPECTORS

I want to talk a minute about those inspectors. I am not speaking of inspectors personally or individually. Some of the most conscientious and best men I know are inspectors, but the inspection system as it is used everywhere is wrong; and there is not any need for it. Inspectors are non-productive only; they cause a great bill of expense and give nothing for it. What is the process in the average factory? A man is starting up on a screw machine, he is making a lot of pieces, he has made ten thousand pieces, probably, and they are turned over to the inspector. The inspector begins to work on them. What does he do? He lays down one pile here. What are they? He knows none of them are right, but he lays down these because they are the best in the lot. Then he lays down this pile over here, and those are not good enough. He thinks he cannot let those go through, they must be fixed over again. He lays this pile over here, and sometimes it is the largest pile, and he is going to scrap those, and he looks wise and proud and thinks there is a great field for him, and a great thing in the future, and what would become of the company if he were not there to save it. That is the way he feels about it. The pile on the right that he is going to use contains only the best there are in the lot. With the method I told you about, every one is right, because the men do not make any that are not right. What can the inspector do to them? Nothing. As to the second pile of parts the inspector has made that are not right, and has to be fixed over, the cost is more than if they had been made right in the first place, and then the parts are not satisfactory, but you conclude to use them. In addition, there is the very large pile that you throw into the scrap heap. All the material and all the work done on this are thrown away, because you have so much confidence in this system of inspection. It is not necessary.

You say, "Well, we have to have inspectors because we buy material from other people who do not make it as we want it." That is all right. That is the only need you have for your inspectors. You should train the people you buy from to know that you will not take their work unless they send it to you absolutely right; then you do not need any inspectors

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at all. That is rather radical, extreme. You are not making automobiles that way. I do not know of anybody who is. I know one plant that does not have as many inspectors in proportion as some others do, and it turns out fairly good work. But the way I have described is right; the ideal way. We do not look upon the undertakers as particularly progressive people. They are a non-productive class, and so are the inspectors, just as non-productive. Do you get any dividends, gentlemen, out of non-productive labor? I never knew anybody who did.

That is the art of it all, the great secret; the art of knowing how. You can do that way if you try; you can teach your men to work that way if you go at it right. It has been done. It can be done. It is the right way, and there is no other right way. The right way, my mother said when I was a little boy, and I never forgot it, is just as good as any other way.

I am mighty glad our friends from across the water came over here. I am glad they have been in some of our plants. I am only sorry that they have so little time to spend in our plant and I want to say to you that you are welcome to come to our plant and stay there a month, a week, or a day, and I will furnish an intelligent man to show you everything that we have there. We will not keep anything up our sleeves, but will tell you all about it and help you all we can, because, gentlemen, I mean it when I say that the more good automobiles that are made, the better it is for all of us, the more will our car be in demand, because the demand cannot be filled. Cars will wear out, however well they are made, and the people are anxious to ride in them; and when a man has once taken a long tour through the country with his family, or other congenial company, and gets away up onto those beauty spots, and those high peaks of land where he looks out upon the beautiful panorama, and has not the handicaps that he has in the steam cars or the boats, he simply stops his car and looks and takes it all in, and will talk about it until fairly satiated with its beauty: he passes on and rides all over this country in that way. He can go fifty miles a day, or one hundred, or two hundred at will. There has never been any other device of man or the Almighty that he could do that with. That is the reason thirty millions of people in this country want an automobile. That is the reason thirty million people ought to have an automobile. That is the reason we all ought to get busy and make them all the automobiles they want, and let's make them good ones.

(Continued applause.)

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# LIST OF SOUVENIRS PRESENTED TO BRITISH GUESTS OF THE SOCIETY

## *I. A. E.-S. A. E. MEETING, JUNE, 1913*

| DONOR | ARTICLE |
|---|---|
| Allen Auto Specialty Company, New York | Letter Wallet |
| Automobile Chamber of Commerce, New York | Handbook of Gasoline Cars |
| Billings and Spencer, Hartford, Connecnecticut | Key-ring and Letter-opener |
| Bosch Magneto Company, New York | Slide Rule |
| Continental Motor Mfg. Company, Detroit, Michigan | Steel Tape—Metric and English |
| Wm. Cramp and Sons, Philadelphia, Pennsylvania | Descriptive Book of Works |
| Disco Company, Detroit, Michigan | Folding Steel Rule — Metric and English |
| Edison Storage Battery Company, Orange, New Jersey | Voltmeter |
| Ferro Machine and Foundry Company, Cleveland, Ohio | Gold Clutch-pencil |
| Peter A. Frasse and Co., New York | Cigar Cutter and Stick-pin |
| General Electric Company, Harrison, New Jersey | Playing Cards in Case |
| Jackson Motor Shaft Company, Jackson, Michigan | Leather Memorandum Book |
| Metropolitan Section, Society of Automobile Engineers | Official Note-case and Guide |
| Motor Age, New York | Horsepower-computing Chart |
| National Tube Company, Pittsburgh, Pennsylvania | Gold Watch-chain; Ladies' Hat-pin |
| New Departure Manufacturing Company, Bristol, Connecticut | Ball-bearing Circular Slide Rule |
| Packard Motor Car Company, Detroit, Michigan | Bronze Paper-weight |
| Pyrene Manufacturing Company, New York | Fire Extinguisher with Motor Bracket |
| Schrader Valve Company, New York | Tire Gage |
| Sears-Cross Company, New York | Leather Memorandum Pad |
| Spicer Manufacturing Company, Plainfield, New Jersey | Horsepower-computer and Slide Rule |
| Stromberg Motor Devices Company, New York | Speed-computing Chart |
| Splitdorf Electrical Company, New York | Silver Drinking Cup |
| Timken-Detroit Axle Company, Detroit, Michigan | Steel Rule |
| United States Industrial Alcohol Company, New York | Freezometer |
| United States Rubber Company, New York | Fraction Adding-Machine |
| Walter Motor Truck Company, New York | Silver Pencil |
| Western Electric Company | Chau-phone |
| J. H. Williams and Company, Brooklyn, New York | Cigar-box Opener and Wrench |

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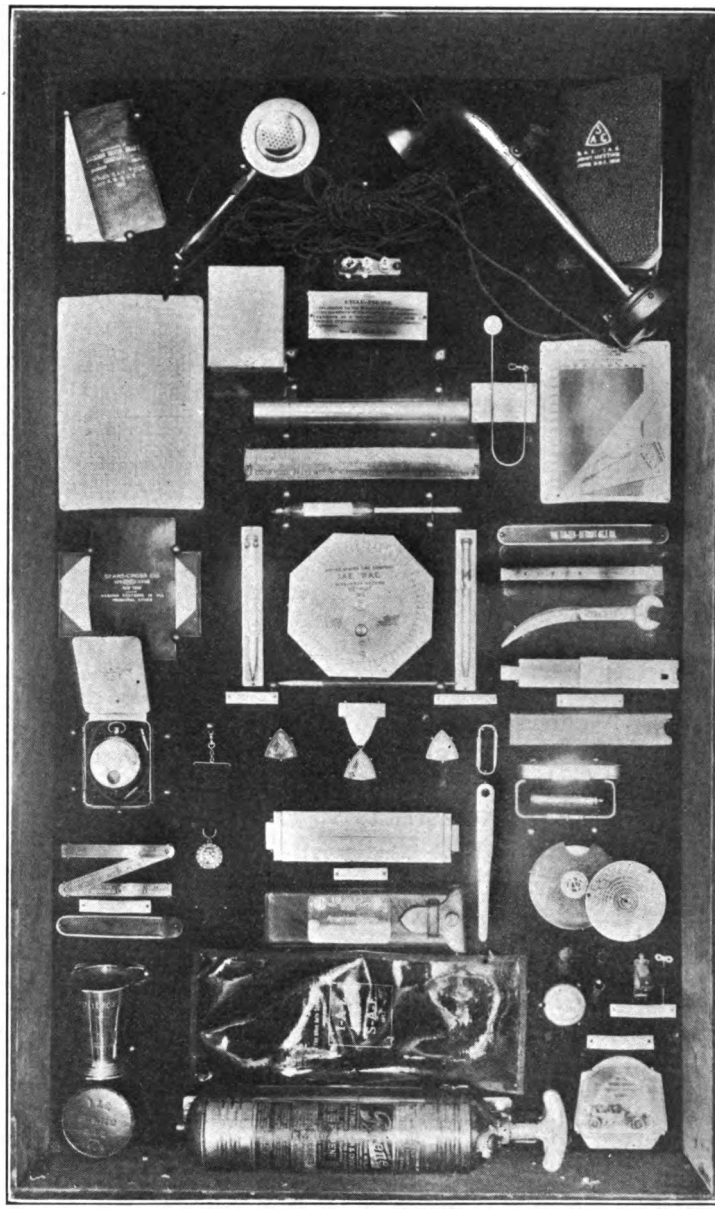

Set of Souvenirs Presented to British Guests of the Society

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## TREASURER'S REPORT AS AT SEPTEMBER 30, 1913

| | | |
|---|---|---|
| Balance in bank October 1, 1912 | $173.77 | |
| Balance on hand October 1, 1912 | 8.39 | |
| | | $182.16 |

RECEIPTS FOR FISCAL YEAR.

| | | |
|---|---|---|
| Dues, 1911 and prior | $90.00 | |
| Dues, 1912 | 945.00 | |
| Dues, 1913 | 18,332.21 | |
| Dues, 1914 | 15.00 | |
| Initiations | 8,231.59 | |
| Pins | 1,044.00 | |
| Folders | 869.35 | |
| Publications | 838.60 | |
| Binders | 32.20 | |
| Laboratory Apparatus | 16.60 | |
| Dinner | 2,052.00 | |
| Interest | 146.54 | |
| General Committee on Arrangements | 4,372.73 | |
| Badges | 265.00 | |
| Miscellaneous | 73.63 | |
| Return of Expense Advanced | 166.91 | |
| | | 37,491.36 |
| | | $37,673.52 |

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| | | |
|---|---|---|
| Total Receipts for Fiscal Year | | $37,673.52 |

DISBURSEMENTS FOR FISCAL YEAR.

| | | |
|---|---|---|
| Salaries | $9,203.82 | |
| Postage | 1,254.03 | |
| Pins | 846.70 | |
| Binders | 214.25 | |
| Publications | 8,613.17 | |
| Folders | 283.75 | |
| Rent | 2,041.69 | |
| Telephone and Telegraph | 523.07 | |
| Carfares | 28.95 | |
| Auditing | 355.65 | |
| Furniture and Fixtures | 372.17 | |
| Stationary and Supplies | 1,057.45 | |
| Convention Reporting | 654.25 | |
| Expressage | 408.37 | |
| Dinner | 2,579.50 | |
| Meeting Expense | 3,610.11 | |
| Interest | 160.00 | |
| Notes Payable | 1,000.00 | |
| Miscellaneous | 813.76 | |
| Expense Advanced | 200.00 | |
| General Committee on Arrangements | 546.28 | |
| Badges | 243.60 | |
| Donaldson Monument | 250.00 | |
| | | 35,260.57 |
| | | $2,412.95 |
| Balance September 30, 1913— | | |
| In Bank | $2,412.72 | |
| On Hand | .23 | |
| | | 2,412.95 |

*We hereby certify that the above statement is correct.*

(Signed) GUNN, RICHARDS & CO.,
*Public Accountants.*

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# PAPERS PRESENTED AT MEETINGS OF SECTIONS OF THE SOCIETY

## DETROIT SECTION

### SOME OF THE DIFFICULTIES OF KEROSENE CARBURETION

By P. S. Tice

(Member of the Society)

Most of the characteristics of kerosene, as it compares with gasoline, have been discussed of late, notably in the meetings of our several Sections and in the motoring press. Hence, but a brief summary of its chiefly interesting physical properties will suffice at this time.

Kerosene is heavier than gasoline and has a higher viscosity coëfficient. It is comparatively non-volatile. Its specific heat is little, if any, higher than that of gasoline; but its latent heat of vaporization is approximately 2.5 times that of gasoline, and apparently lies in the neighborhood of 680 B.t.u. per pound. Its composition, as to range and nature of substances comprising the mixture, is more diverse than that of gasoline; and, as received from the producer and seller, it uniformly carries more, and more widely assorted, foreign matter in suspension.

Of these properties, the first, the greater weight per unit volume of kerosene, is unimportant, except insofar as it is an advantage, in that a greater quantity of energy can be carried in the same space in a car.

The matter of the relative viscosities of the two fuels is an important one, however. Obviously, if mixture proportions remain about the same for the two fuels, a carbureter will be required to have larger fuel orifices for kerosene. In practice this item presents no difficulty; but in the matter of change of viscosity with temperature change, the first great difficulty arises. If we parallel the cases of .755 sp. gr. (58° B.) gasoline and .817 sp. gr. (42° B.) kerosene, in respect to increase of flow through a small orifice with rise in temperature, the result is highly interesting. According to Sorel, a French physicist who has done a great deal of research work in carburetion, kerosene of .817 sp. gr. will

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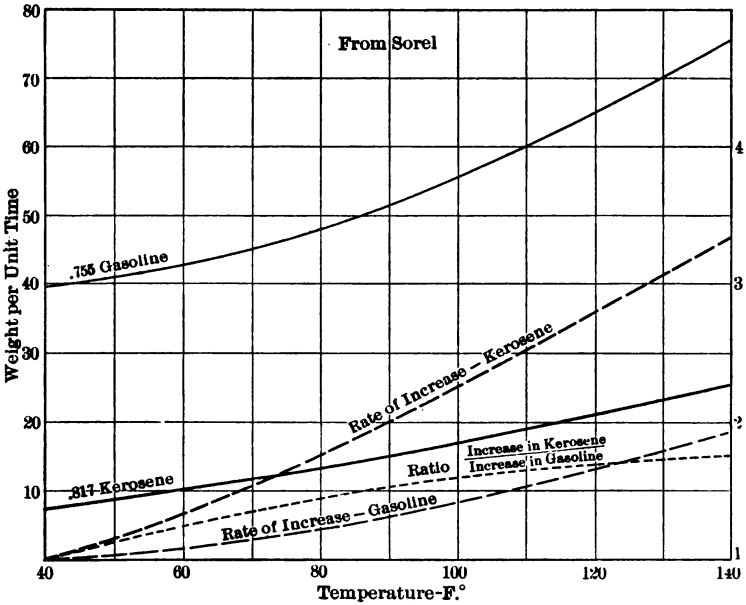


be discharged from a small-bore passage at twice the rate at 90° F. as at 40° F., while at 140° F. the discharge will be 3.33 times that at 40° F., the pressure differences under which these discharges are made being identical. In the case of the .755 sp. gr. gasoline, if the discharge at 40° F. is taken as unity, that at 90° is found to be 1.30, and that at 140° F. 1.92, with the same head and same passage as in the case of kerosene. In other words, with the same head and same passage for the discharges of the two fuels, the rate of increase in kerosene as compared with gasoline discharge, with a temperature rise from 40° to 90° F., is 1.52; and, over the range from 40° to 140° F., the relationship of the rate of increase of kerosene to gasoline is 1.74.

These facts tend to result in practice in an aggravation of one of the most annoying troubles experienced by the average motorist of today—that of nursing the motor until it and its carbureting system have attained the working temperature conditions under which the latter has been adjusted. The colder the weather, or the more economical the carbureter adjustment, the longer will it take to "warm up."

It is a safe assertion that a carbureting system of conventional type cannot be made to operate flexibly and economically without an input of heat to the mixture ingredients sufficient, or nearly sufficient, completely to vaporize the fuel. This being the case, the range in temperature of the fuel may exceed that noted above; and, if this does occur, the mixture proportions will be greatly disturbed as the result of comparatively small temperature variations. This effect may be further aggravated in the case of kerosene, as compared with gasoline, because of the

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fact that a wider variation of temperature values may be experienced in a heated carbureter using the former fuel.

Even with the extensive heating practiced today in gasoline carbureters, a temperature of 100° to 120° F. is seldom exceeded. In kerosene devices of conventional type the temperatures of the mixture ingredients will often approach three times these values. The foregoing explains in part the difficulty experienced in securing compensation or proper automatic control of the mixture proportions in the conventional type carbureter to which heat is applied to adapt it to the use of kerosene.

The relative specific heats of the two fuels have only an indirect bearing on the matter of carburetion. There is not over .04 B.t.u. per pound difference in the two cases. However, since the boiling or vaporizing temperatures of kerosene are consistently from 2 to 2.5 times higher than for gasoline, it follows that 2 to 2.5 times the heat input is required to bring kerosene to the temperatures where vaporization begins.

But even this difference in the two fuels is of comparatively little moment, in view of the difference existing between the latent heats of vaporization. As stated, the value of this quantity, in the case of kerosene, is approximately 680 B.t.u. per pound. This brings the total heat of vaporization of kerosene, from an initial temperature of 40° F., up to approximately 900 B.t.u. If complete vaporization is sought in the intake system, this very considerable heat input, in the short time available, means the employment of high temperatures—temperatures so high, in fact, that unless the means of their application is very well thought out, prohibitive difficulties will be encountered.

It should be noted at this point that the difficulties alluded to are almost wholly attributable to the heterogeneous nature of the compounds composing the mixture known as kerosene. They are not all of one series, nor of two series, but are, apparently, haphazard compounds resulting from the cracking and other treatment of the oils from which we ordinarily speak of them as having been distilled. Whatever the causes are, the fact remains that certain of the compounds entering into the mixture known as kerosene are easily broken down to form others and to free some of the carbon. This can readily cause coking in the passages, which will, in a short time, interfere with the operation of the carbureting device. The foreign matter seems to be largely capable of removal by mechanical means; but certain samples have been found to contain minute particles of waxy or paraffin-like substance, readily seen under the microscope, even after the ordinary careful filtering through chamois. Ordinarily these particles are flaky and translucent, and appear to be clean. But if the fuel is subsequently heated to vaporizing temperatures, these waxy particles become grouped in sufficient numbers so that they can be seen with the unaided eye; and the microscope shows them to be shot with single and nested particles of carbon.

### RELATIVE NON-VOLATILITY

The relative non-volatility of kerosene is the property that has proven to be the greatest stumbling block in the development of a com-

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mercial kerosene carbureter. It is a practical impossibility to start a cold automobile motor on kerosene, with a cold carbureting device, and an ordinary system of intake piping for the distribution of the mixture. Poor as are the present grades of gasoline, it is no great matter to get started under even the most adverse temperature conditions that we experience in this latitude. There are certain of the components of 58° B. gasoline that volatilize below 50° F. It is true that they are present in small quantity, but after enough of them has been pumped into a motor, by aid of strangling or other means, a start is the result; and the subsequent heating of the motor does the rest.

In the case of kerosene, however, the first members of the mixture to vaporize do not do so below 135° to 140° F. Hence the futility of attempting a cold start on kerosene.

## TESTS RESULTS

In the following it will be attempted to present some few of the interesting and generally applicable results of a preliminary investigation of kerosene fuel undertaken late last year in the laboratory of the Holley Brothers Company. The first steps in the investigation proper dealt with the conditions necessary of fulfilment to secure the starting of a cold motor directly on kerosene. The motor used was of one of the best known four-cylinder bloc constructions, bore 3.75 inches, and stroke 4 inches. A simple T manifold with short common branch was used; and attached to its flange was an 18-inch length of .50-inch o. d. copper tube, having a bore of .4375 inch. This tube was arranged vertically, and its lower or intake end was adapted to take a series of throat pieces of approximately venturi form. No throttle, in the ordinary sense of the term, was fitted, the sizes of the throat openings determining the capacities of the carbureter. Mounted below the tube, and in axial alignment with it, was arranged a jet, adjustable for height in its mounting. The relative quantity of fuel discharged from it was determined by the closeness with which the jet outlet was made to approach the point of greatest air-stream constriction through the throat piece. A small-bore tube soldered into the jet piece dipped into a beaker of kerosene of .817 sp. gr., the beaker being carried on one pan of a sensitive scale. The apparatus was completed by a winding of 40 feet of No. 18 Nichrome resistance wire over a thin mica insulation on the .50-inch carbureting or vaporizing tube. The winding was thoroughly lagged to minimize heat loss, and was connected into the 120 v. d.c. lighting circuit, in series with a rheostat. An ammeter gave readings of the current passed. A thermometer mounted in the manifold, with its bulb directly over the outlet of the carbureting tube, showed the temperatures of the mixture issuing from the tube.

This means of heating the tube, and therefore the mixture, was adopted because of its simplicity and ready controllability, and because it permitted an approximate calculation of the heat input to the fuel.

After the necessary preliminary runs, to determine the jet setting, etc., had been made, the first work done with the apparatus was the

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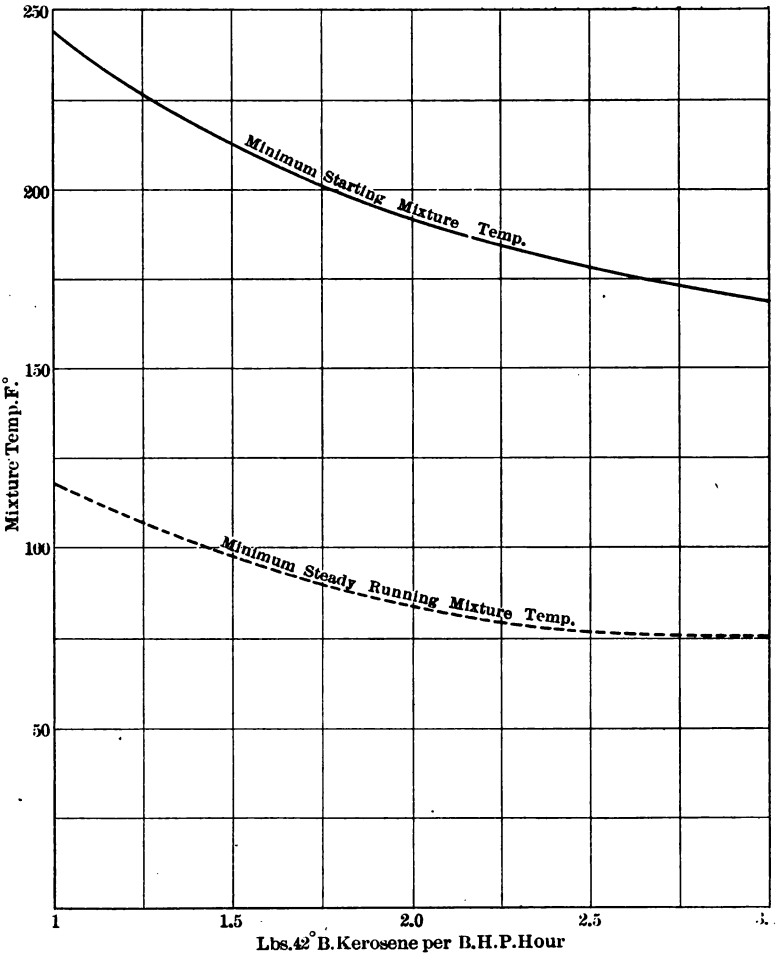


Sheet I

determination of the heat input to the fuel, necessary to secure starting of the cold motor. For convenience sake, and as expressing the results almost equally well for the present purpose, the simple mixture temperatures as shown by the thermometer will be dealt with in the following. Current was passed through the heating coil at such a rate as to cause its temperature to rise fairly slowly, and the motor was cranked until it started, the temperature of the mixture being noted at the instant of starting. A run was then made without changing the jet setting, the temperature of the mixture being controlled to maintain motor speed and torque at the predetermined maxima for the throat piece in use, reading being taken of the time needed for the consumption of 100 gr. of the

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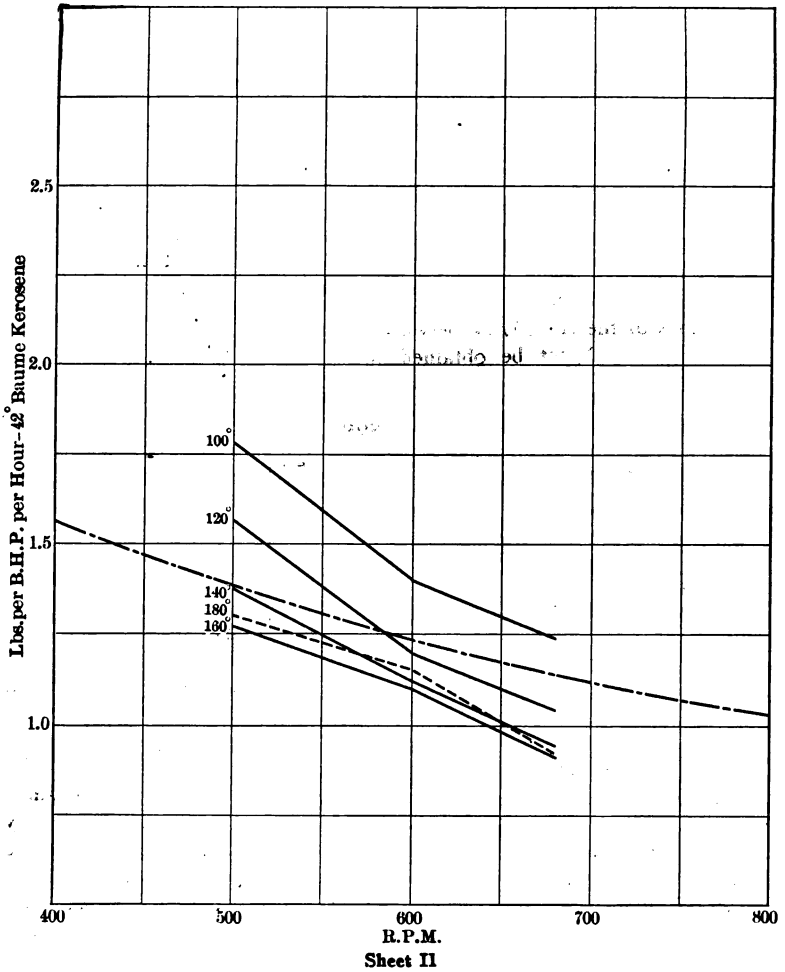


Sheet II

kerosene. After the completion of the fuel-consumption portion of the run, the current flow through the coil was decreased, to lower the mixture temperature progressively and slowly, and a reading was made of the mixture temperature at which the motor began to miss or pound or show any signs of unsteadiness. Each subsequent run of this series was made after bringing the motor temperature back to that at which the first start had been made, very approximately 65° F., and after very slightly altering the setting of the jet.

### STARTING AND STEADY RUNNING TEMPERATURES

These runs give us data from which are constructed two curves: Mixture temperature necessary for starting cold, referred to fuel con-

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sumption in lbs. per b.hp. per hr.; and minimum mixture temperature of steady running, also referred to the lbs. per b.hp. per hr.

The first of these curves shows that a starting mixture temperature ranging from 170° to 250° F., depending upon the richness of the mixture, is necessary to secure a start, the higher temperatures being necessary for the leaner mixtures. The tendency of this curve is toward flatness with an increasing ratio of fuel in the mixture, indicating that even a very generous priming will not reduce the temperature necessary for starting to a value much below 170° F. The normal rate of fuel consumption of the motor, under the speed and load conditions of these runs, lies between 1.25 and 1.50 lbs. per b.hp. per hr.; thus it is seen that both fuel and air will require to be raised to about 220° F. to secure a start without priming, the temperature of the motor being very close to 65° F.

The curve of minimum steady running temperatures shows mixture temperatures ranging from 120° to 76° F., as the minima over the mixture proportion range giving consumptions of from 1.00 to 3.00 lbs. per b.hp. per hr. With the normal consumption of the motor, at the speed and load conditions of the runs, lying between 1.25 and 1.50 lbs., it is seen that steady running could not be obtained with a mixture temperature of less than 100° F.

### OPERATION ECONOMY

The second set of curves shows the influence of mixture temperature upon the economy of operation. Each of the several points on any one curve was obtained under the same speed and load conditions, the temperature of the mixture being varied by means of the rheostat in series with the heating coil, and the mixture proportion adjusted at the jet to maintain the speed and load. It is notable that with each of the combinations of temperature and mixture quality, as marked by the points, the output of the motor was the maximum that could be obtained from it with the throat piece in use. These curves show very graphically what an influence the heat input, as represented partially by the mixture temperature, has upon the economy of operation. Probably the most interesting thing shown by this set of curves is the fact that the temperatures of most economical operation cover the same range in each case, i.e., 150° to 170° F. Subsequent runs with an enlarged and modified apparatus show this same range of temperatures as being most economical almost up to the full load and speed capacity of the motor.

One of the things chiefly noted in the making of these runs was the fact that each mixture temperature, as representing a rate of heat input to the fuel, has its own sharply defined mixture proportion. Even a very slight change in proportion, either way from the best, will, if the temperature is maintained constant, cause a marked falling off in the output of the motor. And the converse is equally true.

The third set of curves shows the same points as in the foregoing set, but plotted to coördinates of fuel consumption and motor speed, each curve representing the consumptions at a certain mixture temperature. It will be seen that the consumption decreases as the temperature increases,

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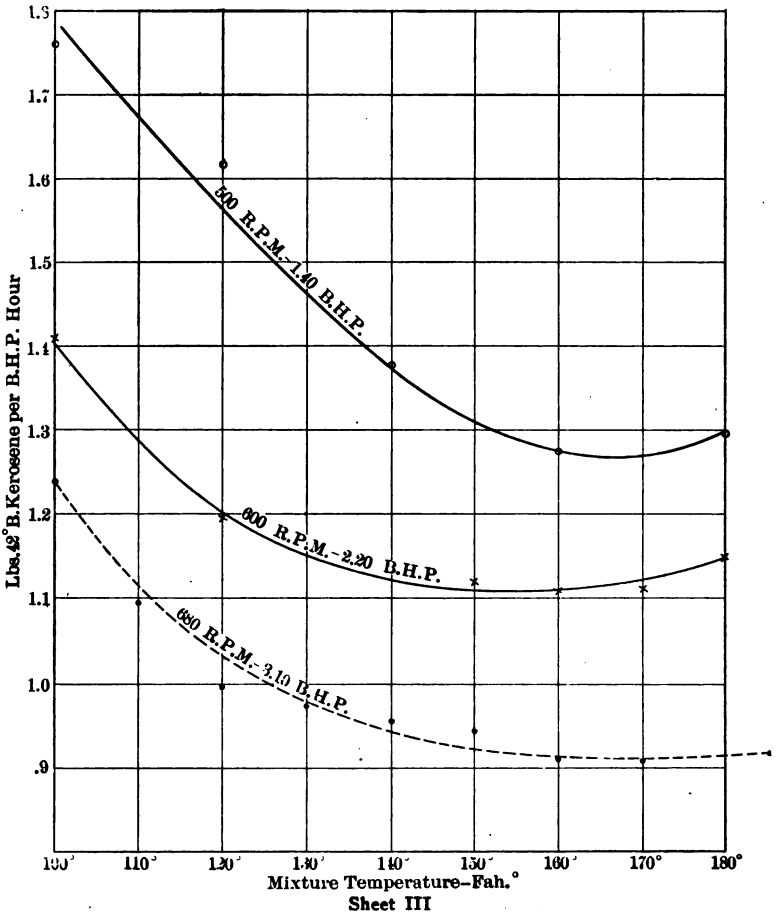


up to 160° F., and that beyond that value it increases. The broken-line curve extending from side to side of the sheet shows a representative plotting of fuel consumption under the same conditions on the same motor, as obtained with one of our standard carbureters using gasoline, and with no heating whatever. This gasoline curve presents a very good performance in economy, but it does not compare with the 160° F. curve for kerosene.

It is, of course, realized that all of the runs shown were made under conditions of close throttling of the motor.

## DISCUSSION

W. S. HOVEY:—Our engines are almost exclusively the two-cycle type and devoted to steam railroad and marine work. For marine work

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we have been developing along the line of a hot bulb pipe, fuel-injected design, and have accomplished considerable, perhaps more, with the lower grade oils than kerosene. With the smaller two-cycle engines, which are used throughout the country on the railroad cars, our results have not been entirely successful. We have been experimenting more or less for years.

### HARROUN KEROSENE CARBURETER

V. W. KLIESRATH:—I had the pleasure of riding from Indianapolis to Toledo yesterday and the day before in a car equipped with a Harroun carbureter, in which we burned nothing but what is known as Perfection grade of kerosene. The fuel is preheated by means of a nozzle heated by passing all of the exhaust gases through the carbureter. The mixture is cold, taking cold air. In the run started from Indianapolis I rode in the car beside the driver and did not notice any difference whatsoever between the kerosene operation and gasoline operation. In other words, it was possible to accelerate just as fast with the kerosene as with the gasoline. Also, during the entire trip there was no smoke noticeable, running with either the cutout open or with the muffler inserted. When we stopped at several little towns, for as long as fifteen or twenty minutes, we left the engine idling; there was absolutely no sign of smoke or noticeable odor. We made the entire run at an average of about eighteen or nineteen miles an hour, having the great pleasure of getting on some of the nice roads that were left by the recent floods, and having to ford the rivers three or four times.

It was quite amusing to note the expression on the faces of the different garage keepers when we ran in and asked for kerosene. They wanted to know whether we were not making a mistake; put the kerosene in, stood there and chatted, always with the motor idling in front of them. When we reached Fort Wayne we stopped for the night and left the car standing in front of the hotel all night. About 7:30 in the morning, with the motor cold, in less than one minute's time we were running on kerosene.

The entire test covered over 2,100 miles. Less than one gallon of gasoline was used for starting and heating the carbureter on 350 miles of the test. I happened to see the internal parts of the motor. There was absolutely no sign of carbon.

The car had the smallest type of Bosch magneto, known as the D. U. 4 independent high-tension. The car was an Overland. I believe it is Model 69, 4-cylinder, 4-inch bore, 4½-inch stroke. No difficulty was presented, no overheating of any kind. We made tests throttled down in the neighborhood of five or six miles on the high gear; accelerated to about forty-six miles per hour, which speed was held a distance of about six miles; when we immediately shut the throttle and tried lower throttle results again, and made an acceleration test, which was very good.

CHAIRMAN C. T. MYERS:—I will read a paragraph or two from an article in *The Automobile* (April 24, 1913, page 908), giving conclusions

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and some figures of some fuel tests made in Indianapolis. "In general, the deductions to be drawn from this series of tests are that:

"1. As handled by Harroun's new carbureter, the low-grade kerosene, known as Perfection Oil, and selling practically everywhere at one-half the cost of gasoline, gives better mileage, gallon for gallon, than any of the other fuels tested; gives more than twice as much mileage, dollar for dollar, as gasoline; gives more speed than any of the other fuels; acceleration almost as good; carbonization, nil; smoking, negligible; general action, the same as gasoline, except for the necessity of preheating the fuel.

"2. The lower the gravity of the common petroleum distillates the better economy in miles per gallon and cents per mile—excepting Motor Spirit, which seems to fall between gasoline and kerosene oil in these considerations." Then there is a table of speed tests over a measured mile and one-half mile. "Fuel, kerosene. Gravity, 43. Miles per hour, 51. Average miles per hour, 49.2. With Motor Spirit, gravity 62, the average is 46½ m.p.h. With gasoline, gravity, 60, the average is 43.2 m.p.h." Mr. Kliesrath, do you know whether any carbureter adjustments were made in changing from one fuel to the other?

V. W. KLIESRATH:—Absolutely none, except that we had a variable needle-valve adjustment on the dash. The difference noticeable between gasoline and kerosene was that we used two small notches which represent a lift of the needle of practically less than two-thousandths of an inch. In using gasoline we used a greater opening than with the kerosene; and with the Motor Spirit approximately the same. No air adjustments whatsoever were made.

CHAIRMAN MYERS:—The acceleration test figures from ten to thirty miles per hour were practically the same in every case; kerosene, 16.4 seconds; gasoline, 16.1; Motor Spirit, 16.0. The fuel economy results were: 43 gravity kerosene, 22.2; 49 gravity, 21.6; Motor Spirit, 20.4; gasoline, 20.0 miles per gallon. Those are pretty good results all the way through. Price per gallon: 43 gravity, 8 cents; 49, 10 cents; Motor Spirit, 13 cents; gasoline, 16 cents.

The table also gives ton-miles per gallon, 26.64, 25.92, 24.48, 24.0; cost per ton-mile, .0029 for the 43-gravity kerosene, .0038 for the 49 gravity; .0054 for the Motor Spirit; .0067 for the gasoline.

V. W. KLEISRATH:—The average from Indianapolis to Toledo was around 17 miles per gallon. Yesterday a goodly part of the distance had to be traveled on second speed, on account of the extremely bad road conditions after leaving Fort Wayne. These test results that are given for the mile were secured on the Indianapolis Speedway; maximum acceleration and average speed per mile tests. There was always an average taken, I believe, of three trials.

A MEMBER:—What was the compression in that car?

V. W. KLIESRATH:—The motor was identically the same as received from the Overland factory. The compression was the same as for gasoline.

A MEMBER:—Is there any objectionable odor?

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V. W. KLIESRATH:—None whatever. The method of starting is this: From a tank of about two gallons' capacity on the running-board a ¼-inch flexible copper tube runs to a point in the manifold, through a little button valve on the dash. The time you keep your foot on that gasoline button is the same that you hold the electric starter actuating device down. The motor probably makes in the neighborhood of four or five turns; when you release that button it takes right hold. Early in the morning when the cylinders are cold it probably runs on two or three cylinders for a period of about half a minute, when it straightens out. The gasoline is lifted into the motor by simply the suction through the nozzle. The kerosene is not closed off during starting; that is, the nozzle is open all the while; the carbureter bowl is always full of kerosene. The gasoline is fed in through a separate nozzle, through a little spring plunger on the dash, which automatically shuts off the gasoline. The inlet manifold is the same as regular on the Overland car. The only change in the motor is in making a return exhaust bend direct to the carbureter, through the carbureter, then to the muffler. We ran with the muffler cutout open and then closed. It does not make any difference, because the entire heat of the exhaust passes through the carbureter in either case. Identically the same nozzle as for gasoline was used for the kerosene.

P. S. TICE:—Do you attempt to heat more greatly the fuel or the air?

V. W. KLIESRATH:—The fuel.

P. S. TICE:—Which does the exhaust gas come chiefly in contact with?

V. W. KLIESRATH:—With the nozzle itself. The nozzle itself sits in a core, which is heated to almost a cherry red by the exhaust. It is right above the bowl. The bowl becomes so hot that you cannot hold your hand on it any length of time very comfortably.

P. S. TICE:—Have you found that upon shutting down the motor, fumes of kerosene were coming off from the float chamber?

V. W. KLIESRATH:—No, none whatsoever. That was shown in Toledo yesterday, after completing a run of two hours' duration without a stop.

P. S. TICE:—Have you had any trouble with accumulations of foreign or other matter in the nozzle? Have you had any trouble with nozzle obstruction?

V. W. KLIESRATH:—Not so far. In about 2,100 miles nothing like that has been experienced.

P. S. TICE:—What do you do to the fuel before you put it in the tank?

V. W. KLIESRATH:—We do not strain it at all; just run alongside the garage and let them pump it in, dirt and all. Another amusing thing is that when we examined the bowl we found a tablespoonful of water, which did not seem to affect the operation.

P. S. TICE:—I would like to know how the water could lie in there if heated up as you state.

V. W. KLIESRATH:—I could not explain that very well. My theory is that it was simply drawn through the nozzle in the form of steam or vapor.

P. S. TICE:—The most astonishing point to me in your experiences is

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that you had no trouble with dirt in the fuel. That is one of the things I have had the greatest trouble with. To what temperature do you heat the kerosene in the float chamber?

V. W. KLIESRATH:—I believe it reaches a temperature of somewhere around 300°; not in the float chamber, but in the venturi tube. This is the temperature of the fuel before it is mixed with the air; that is, at about the jet surface.

P. S. TICE:—You will find out that the temperature of your mixture is not anything like the atmospheric temperature.

V. W. KLIESRATH:—We have already learned that. We found out what is necessary to throttle low, and I think that is where the entire success of the thing has been brought about. If anything, we are still a little low in temperature for low-speed work. I have seen the motor idle for twenty minutes alongside of the curb without the least sign of any smoke. We can make it smoke a little by leaving the spark fully advanced. With the spark at top center there is not any smoke whatever, or any odor from the muffler, but with the fully-advanced position running idle at the curbstone you do get a slight odor and a very slight smoke. That shows how very close we are to the critical point.

P. S. TICE:—It shows, of course, that the exhaust temperature is higher with the spark late?

V. W. KLIESRATH:—Exactly.

P. S. TICE:—We, of course, have had kerosene carbureters on cars. We kept a Ford motor running on the block at 260 r.p.m. from Saturday morning to Monday morning without any change in anything, just kept it idling. We kept a watchman to note the time if it did stop. On Monday morning the exhaust was as it was when we started. The kerosene-heating device was as thorough as was permissible. Have you found that it has been more difficult to get the necessary heating under idling conditions than any other?

V. W. KLIESRATH:—Yes.

P. S. TICE:—Some measurements of exhaust temperature, which we made in connection with this work, showed that under idling conditions the temperature of the exhaust gas, upon entrance into the carbureter, remained about 480° F. It is extremely difficult to utilize the necessary amount of that available heat in a carbureting device because so much of it will be lost by radiation to the outside air, and so very little of it, relatively, can be put into the fuel.

V. W. KLIESRATH:—I believe that point has been overcome by the torch or blow nozzle about the kerosene spray nozzle.

P. S. TICE:—It has been my experience that we cannot heat the liquid in the jet or in the float chamber to a sufficient extent, and that the most effective or efficient way of transferring heat into the fuel is to put it largely into the air in the first place.

V. W. KLIESRATH:—In your experiments did you use cold air or preheated air?

P. S. TICE:—We have used every possible variation, anything that rhyme or reason could suggest.

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V. W. KLIESRATH:—Mr. Harroun uses entirely cold air, and has not as yet found it necessary to make any air adjustment.

P. S. TICE:—We have found that prehating air as in gasoline carbureters is not the method to employ.

V. W. KLIESRATH:—No, we found very unsatisfactory results in that way.

### WATER INJECTION

C. H. TAYLOR:—I would like to know if either of the gentlemen has ever used any water injection with the kerosene. That is, deliberately, apart from the water that lay in the bottom of the bowl that Mr. Kliesrath spoke of.

V. W. KLIESRATH:—Some time ago I witnessed, in connection with the ignition equipment of a certain engine, a test in which they did use an injection of water with the fuel, but preheated air was used. I have not had experience of it in the case of cold air.

P. S. TICE:—We have never used water injections in any of our work, because at the start of the investigation we discovered that the only time at which pounding or bumping, or apparent preignition, whatever you wish to call it, occurred, was when the fuel was poorly vaporized, or when it was present in the mixture in insufficient quantity. In my curve of minimum mixture temperature on steady running (Curve Sheet I) that was very apparent. The nozzle was set in the carbureter to supply fuel at a certain rate, at a certain number of pounds fuel per brake-horsepower hour. Then the heat input to the fuel was decreased progressively; when it dropped to a certain point, practically following along that curve, this pounding would begin, and it seemed like preignition. I am at a loss to explain what causes it. I wish some one would throw a little light upon it. Of course, it can occur and be really preignition with very high mixture temperatures; but when the air is not preheated, when most of the heat enters into the fuel, bumping does not occur, unless the fuel is poorly vaporized.

### IRREGULAR MIXTURE IN CYLINDERS

HERBERT L. CONNELL:—In relation to Mr. Tice's last remarks, I can cite a similar experience. This spring I have been riding downtown with a friend who drives a 1910 Ford Model T. This peculiar knocking or bumping noise occurred almost every morning when we started out on low gear. It would often continue for one or two blocks and then the motor would stall. After cranking and repeating the whole performance once or twice the knocking would disappear and the motor would then run perfectly. The knocking sounded to me exactly as it does when the pistons start to stick, and yet there was absolutely no indication of "freezing up" in this case. The trouble seemed to be entirely cured by replacing the old 1910 Kingston carbureter by one of the latest models of the same make.

P. S. TICE:—That occurred only at the time of starting out in the morning?

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HERBERT L. CONNELL:—Yes.

P. S. TICE:—It may be all of a piece with this condition I have spoken of.

HERBERT L. CONNELL:—The point I want to bring out is that it happened the same with gasoline as with the kerosene. It seemed a characteristic possibly of the motor and carbureter rather than of the fuel.

P. S. TICE:—A bit of experience tends to bear out my conclusion in that connection. In one of the kerosene types that has been put up in our plant, and worked out on a Ford car, there was a tendency to run lean in fuel when opening the throttle quickly. With this kerosene carbureter the motor would bump very markedly, every time the throttle was opened at a speed below ten miles an hour. It did not matter how far the throttle was opened, all one had to do was open it, and the motor would knock, but it was a descending scale of knocking; it would start in very strongly and gradually trail off to nothing without any further change in the throttle position. It did not make a bit of difference how warm the motor was or how cold it was, the condition was there.

C. E. COX:—This knocking in the motor that has been described seems to be due to the change in the mixture or a poor mixture. I have tried to account for it a number of times by the fact that one cylinder was getting a weaker explosion than the others, which caused some change in the action of the reciprocating parts, and a knocking or pounding which disappeared as soon as the cylinders were getting uniform explosions. That explanation might apply to the car in the morning when it is cold, one of the cylinders getting unequal mixture, and, therefore, unequal explosion; or it might occur with quick opening of the throttle, and would disappear as soon as the motor speeds up and the mixture becomes uniform. It may not be a fault of the motor or carbureter, except for the quickness with which the carbureter adjusts itself to the motor when any change is made in the speed.

W. R. MCCULLA:—In using kerosene on starting a cold motor, in zero temperature, by preheating the kerosene I found that the two center cylinders, on a four-cylinder block motor, would get too rich fuel and the two end cylinders be starved. I got that peculiar bumping noise, which would disappear gradually as the motor got warmed up. By using another method of heating the fuel I got rid of that almost entirely. I have had pretty good success in driving up to about twenty-eight miles an hour. After that the motor would start misfiring and preignite. When using gasoline as the means of starting, I did not get that knocking which I called preignition.

CHAIRMAN MYERS:—I have had similar experience. You will get it sometimes with gasoline, especially if you have a pretty poor grade, or if you are troubled with water, or anything of that sort. Practically all the writers on the subject of carburetion of kerosene agree that one of the difficulties is to get under changing-load conditions a mixture which will fire properly in all the cylinders. It is very easily conceived that some of the cylinders will get a better mixture than the others. I have made tests of motors to determine whether one cylinder was not getting a little more or a little less under a condition of knocking, and found it

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so, although there are a number of causes which can contribute to such a thing. It is very hard to locate.

W. R. McCULLA:—I made a special manifold for the motor I mentioned, using a venturi tube for each cylinder. The test was made at about four degrees below zero. The car had been out all night in the yard. What I was trying to do was start up on kerosene with a very cold motor. I succeeded with very little trouble when I altered the size of the venturis to the four cylinders. I finally got the proper size for each cylinder. Then I did not get the knock.

CHAIRMAN MYERS:—You varied the size of the venturi tube for each particular cylinder?

W. R. McCULLA:—Yes. Of course, that would be a complication to get adjusted right, after the motor was warmed up; so that it was not practical.

P. S. TICE:—What means did you take for heating the kerosene in the first place?

W. R. McCULLA:—An electric heater. But I used very high velocity.

P. S. TICE:—The set of venturis was simply means to secure distribution?

W. R. McCULLA:—Yes, to satisfy myself what caused the knocking, a lean or rich mixture in each one of the cylinders.

A MEMBER:—It seems to me that a large part of the knocking is due to irregular mixtures, for you find the same thing, for instance, in a motor with intake valves in cages, when the cages begin to leak. One particular cage will begin to leak and dilute the mixture in one group or one pair of cylinders. You will find the same thing with a leaky intake gasket, as we used to find some ten or twelve years ago, when the gasoline was a good deal better than it ever will be again. The characteristic seems to me entirely independent of the fuel, except that in the heavier fuels you have a great deal more risk of getting loading and irregular mixtures in the cylinders.

P. S. TICE:—Any conclusion we can come to indicates irregular mixture in the cylinders; that is, uneven distribution. The knocking to which I have made reference was apparently not uneven. Each impulse was accompanied by a sound apparently identical with the sounds from each of the other cylinders, if you see what I mean.

### MANIFOLD DESIGN

A. I. STEVENS:—I would like to inquire whether it is worth while to take into consideration the length and form of the intake manifold? For instance, we were told, I believe, at one of the meetings here, and I have had it confirmed since, that where you have a vertical tube leading up from the carbureter to a long horizontal intake manifold (which is, of course, longer on a separately cast than on a block motor) poor vaporization is more apt to occur. Is this not especially noticeable in low-grade fuel under these conditions? I understand that a low-grade fuel at slow speed will allow a condensing of the gas and cause it to flow back into the carbureter. I would like to find out whether any test has been made in regard to the shape or form of the manifold.

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A MEMBER:—I believe that the difficulty is more in the volume than in the shape of the manifold. I have made some tests on very low-grade gasoline, so low that the residue in the valve chambers and in the intake manifold would stand out in the open air for an hour without evaporating. With the shorter manifold, that is, the one with the least possible volume, there was a minimum quantity of this residue left in the motor. With the longer manifold it not only collected on the sides of the manifold but in the valve pockets when the motor was running with closed throttle, and would stay there until the throttle was opened up and the motor had a chance to clean out. Therefore, I think that using kerosene the volume of the manifold is very important; the greater the volume the more heat you have to supply and the more difficulty in keeping the residue from accumulating in the pipe.

### KEROSENE VAPORIZATION

CHAIRMAN MYERS:—I would like to read from the *Horseless Age* (March 2, 1913, page 637) a paragraph or two of the remarks of Harrington Emerson, in which he outlines what he calls "some of the essentials in the vaporization of kerosene or heavier oils." He says: "The conditions of successful gasification of kerosene or heavier oils are few but essential. They are fully met in the candle or kerosene lamp wick. (1) The delivery of the fuel is in exact proportion to the need, and at exactly the right temperature. (2) The kerosene is wholly consumed as fast as delivered. (3) The heat supplied to gasify the fuel is graduated from the mild warmth sufficient to soften and melt wax up to the highest temperatures required. (4) Sufficient time is given for combustion. If any of these conditions is departed from, however slightly, there is trouble. If a sheet of thin white paper is slowly waved through a candle flame the paper is blackened. The incandescent carbon is cooled and is instantly deposited as smoke or soot. If a lamp wick is turned too high there is not sufficient heat to maintain combustion and a poisonous, evil-smelling smoke results. The same thing happens if the air supply is cut off so as to interfere with perfect combustion. Here are two different causes of carbon deposit, cooling of the carbon, insufficient air, or both combined. If the kerosene lamp wick is turned too low a portion of the gas passes off unconsumed, giving out a mildly offensive smell, causing headache. Probably part of this gas is carbon monoxide, CO, poisonous as well as wasteful." The article cites a large number of experiments made under Mr. Emerson's direction, in which they were attempting to find some sort of carbureter for using kerosene. If the results obtained on this car in which Mr. Kliesrath rode are so good, very likely the principles underlying that carbureter are those which have been named here, and I know we will all be very much interested when that car comes to town.

### CARBONIZATION

P. S. TICE:—It has been my experience that there is less carbon deposit in the motor, using kerosene, if the fuel is even only partly vapor-

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ized; that is to say, if only enough of it is vaporized to make ignition and the propagation of the initial flame in the cylinder certain. Of course, an excess of lubricating oil will carbonize a motor the same as it will with any other fuel, but I wish to state that carbonization is not a necessary result of the use of kerosene.

## ALUMINUM ALLOYS

By C. E. Cox.

(Member of the Society)

This is just a presentation of some data that have been collected by some persons who have made extensive experiments and given me permission to use a certain amount of the data, which show some very interesting things and should bring out further data from manufacturers.

Here are some of the elements that will alloy with aluminum: Iron, Silicon, Manganese, Chromium. These make hard and strong alloys, but they are very brittle and are not used commercially, except silicon, which is present as an impurity in most alloys. Here are some other metals: Cobalt, Nickel, Vanadium, Tungsten, Molybdenum, Tin, Antimony. These make hard alloys, but the melting points are too high, and the cost, in most cases, is so great that they are not considered. Silver and gold also will alloy with aluminum and make very good alloys, but, of course, the cost is out of the question. We next come to magnesium, which has been used in a number of alloys and which gives a very light metal but is not uniform, although it increases the strength of the alloy up to 10 per cent. of magnesium. The strength falls off with a higher percentage. One of the difficulties with these alloys seems to be their hot shortness. The next element on the list is copper, which makes a good alloy, with which we are all familiar, and which is usually designated as No. 12. Zinc comes next and makes a good alloy, but is not much used because it is too brittle. Copper and zinc make good alloys, the one with which we are most familiar being designated as No. 31. There is another alloy called McAdamite, of zinc, copper and aluminum, which compares in properties with the other alloys of copper and zinc with which we are familiar.

Here are some figures for comparison of cast iron and pure aluminum. No. 12 weighs .102; cast iron .261, pure aluminum .097. Magnesium alloys are much lighter than the pure aluminum, in some cases running in specific gravity about two points lighter. In tensile strength we have some tests of magnesium alloys which run more than 28,000, but this is not the average.

Copper aluminum alloys, of which No. 12 is the best example, average about 20,000 lbs. per square inch. This figure is the result of many thousand tests; in fact, the average was a little higher, about 20,500 lbs., from several thousand test bars, which were cast in ordinary foundry practice. Copper and zinc alloys, as shown by Nos. 31, 63 and 101, vary slightly, running a little higher in tensile strength, the average of No. 31, taken from several hundred tests, being about 30,000 lbs. These figures

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ALUMINUM ALLOYS AND THEIR PROPERTIES

| Alloyed with | Properties (Compared to No. 12) | % Al. | % Cu. | % Zn. | % Mn. | % Mg. | Sp. Gr. | Wt. Pounds Per Cu. In. | Tensile Strength | Melt. Pt. °F. | Trade Name | Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Iron..... Silicon..... Manganese... Chromium... | Hard..... Strong..... Brittle..... | | | | | | | | | | | |
| Cobalt..... Nickel..... Vanadium... Tungsten.... Molybdenum Tin..... Antimony... | Hard..... Melting Point too high..... Cost too much.. | | | | | | | | | | | |
| Silver..... Gold..... | Good alloys.... Cost too much.. | | | | | | | | | | | |
| Magnesium.. | Light. Not uniform. Increase strength up to 10% Mg. Hot Short. | | 5.0 | | .5 | .5 | 2.77 | | 28000 | 1202 | Duralumin | (E) |
| | | | | | | | 2.5 | | 18000 | 1200 | Magnalium | (E) |
| Copper..... | Good Alloy..... | 92 | 8 | | | | 2.84 | .102 | 20000 | | #12 | (A) (C) |
| Zinc..... | Good Alloy..... | | | | | | | | | | | |
| Copper and Zinc | Good Alloys.... | 82 | 3 | 15 | | | 3.03 | .109 | 28500 | | #31 | (A) |
| | | 81.5 | 3 | 15 | .5 | | 3.02 | .109 | 30000 | | #31 | (A) |
| | | | 1.75 | 30 | | | 3.35 | .121 | 42000 | | #63 | (A) |
| | | | 2.5 | 19 | | | 3.10 | .112 | 33000 | | #101 | (A) (D) |
| (?)..... | ..... | | 3. | 25 | | | 3.30 | | 37500 | 1040 | Mc-Adamite | |
| | | | | | | | 3.12 | .113 | 44250 | | | |
| For Comparison Cast Iron.... | | | | | | | 7.2 | .261 | 32000 | | | |
| | | | | | | | 7.2 | | 38000 | | | (B) |
| Pure Aluminum. .... | | | | | | | 2.68 | .097 | 10500 | 1216 | | |

(A) Poured at 1225° F.
(B) Poured at 1400° F.
(C) Average of several thousand tests 20500 lbs. per sq. in.
(D) Average of several hundred tests 33000 lbs. per. sq. in.
(E) Can be increased by rolling to 40000 lbs. per sq. in.

show 20,000 lbs. for No. 12 and 30,000 lbs. for the No. 31; cast iron, for comparison being about 32,000 lbs. Pure aluminum, of course, is not to be compared with these, because the tensile strength is only about 10,500 lbs.

We will consider the effect of the treatment of the metal. Castings are the weakest form of the alloys. If the alloys are rolled into sheets or rods or drawn into wire, the tensile strength is greatly increased, which accounts for some of the very high figures we see given for some of the new alloys that are exploited; that is, they will give you the tensile strength for a rolled sheet or for a drawn bar, which runs up, in some cases to

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50,000 or 60,000 lbs. Green sand castings, that is test bars in green sand, average from 20,000 to 30,000 lbs., depending on the kind of alloy.

I have had some practical experience in the decrease in the strength of aluminum at very low temperatures. In Minneapolis, where we operated a number of trucks, we always expected a few broken transmission cases whenever the temperature dropped to 20° below zero or lower. We did not have any trouble at ordinary temperatures. Of course, there were some rather extreme conditions in the way of snow and hard service; the trucks worked harder on cold days, when the teams were out of commission, than at other times. But the results seem to show that very low temperatures as well as high temperature affect seriously the strength of the alloys. I would like very much to hear the views of some of the members present on this point. So far as I know no tests have ever been made with aluminum test bars under low temperatures. It is rather hard to do.

## DISCUSSION.

C. H. TAYLOR.—I would like to ask if there is not another factor of considerable importance, the rate of cooling the aluminum. In other words, it might be affected by the thickness of the metal, and also by the quality of the mold itself; that is, the possible chilling of the metal in the mold.

C. E. COX.—Some tests show that chilling the metal tends to increase the tensile strength of the test bar. In fact, casting in dies increases it in some cases 25 to 30 per cent., but I have never seen results of any tests which show that a little difference in the temperature of the sand or the moisture in the sand, would make any great difference in the strength of the castings.

C. H. TAYLOR.—I brought up the question because I understand that the McAdamite process is based very largely on the chilling of the metal in molds. I believe they use some kind of carborundum lining in the molds for the purpose of chilling. In several cases we overcame the difficulty of castings cracking by inserting iron chills in the molds.

J. P. CARRITTE.—Aluminum and its alloys is a very interesting study, particularly in its elements of uncertainty. The more experience one has had in handling it the more one realizes that there is much yet to learn regarding its possibilities. I have frequently seen a pot of metal properly alloyed, fluxed, stirred, cleaned and skimmed, drawn under pyrometer, poured into two similar molds side by side at the same heat and time and widely different results obtained in strength determinations from the test bars in the different molds—which is difficult to account for. To get the best results proper care and handling in the melting are really more important than the alloying.

Some general shop practice rules that are well to observe to get high value in castings are to use special graphite crucibles, as aluminum has a great affinity for iron and silicon; iron and metal skimmers should be avoided and all stirrers, pots and receptacles of the molten metal should be well chalked or rubbed with graphite.

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When the metal gets to a medium cherry red (not too bright) 1,300° to 1,400° F. by pyrometer, it should be drawn and poured. If for any reason the heat must be held back briefly after it is ready, it should be covered with broken charcoal to prevent oxidation.

When ready to draw flux well with sal-ammoniac or chloride of zinc (½ ounce up to 25-pound heat and one ounce up to 80-pound heat); get well down to bottom of crucible, stir and mix thoroughly, skim, draw and pour immediately, first clearing top of metal from any dross or dirt—with hardwood stick preferred.

Great care should be exercised in the use of scrap; use only the gates, sprues, defective and broken castings (never use turnings, filings, etc., which take up iron from the tools, which is hurtful to the metal). On account of the extreme light weight it is necessary to make larger gates and sprues in order to have the hot metal run properly; the percentage, therefore, of this class of clean scrap in the regular casting process is greater than that of heavier metals.

The metal will run up better, making more solid castings, with large gates from the bottom, avoiding blow-holes, carrying any air and dirt to the top risers.

Metal should not be left in crucibles under heat; always empty the crucible unless another heat is to be made in same immediately when four or five pounds may be left in pot to start the next heat.

Have as little metal left over from casting requirements as possible—gates, ingots, etc., etc. Every time aluminum is remelted it becomes more brittle.

Any sharp corners in patterns (in molding), fillet and heavy lugs or blocks of metal in connection with thin sections should be well chilled, which will help prevent cracks and shrinks.

The strengths obtained in McAdamite castings are due to not only the alloy but more largely the handling of the hot metal in the casting or molding process—by the very rapid extraction of the heat, creating a dense, close-grained and homogeneous metal; the slight excess in weight being, therefore, more than offset in value by the strength and toughness. A molding composition of carborundum, carbon, French clay, charcoal, etc., is used, in the same manner as in ordinary sand practice. The same results from quick chilling would be accomplished by pouring into iron molds, which would involve, however, greatly increased expense and be otherwise impracticable through the heating up of a metal mold on the first pour, thereafter losing the necessary quality of rapid heat extraction.

In many quarters there is a strong opposition to aluminum-zinc alloys, while many eminent metallurgical authorities insist upon their superiority. I think it is largely a question of prejudice, resulting from our different schools, surroundings and associations. Our experience is strongly in favor of the superiority of a proper zinc element and our several standard alloys contain from 6 to 27 per cent.

HARRY GOLDBERG:—I would like to ask Mr. Carritte the composition of that test bar that showed 44,000 lbs.

J. P. CARRITTE.—That is about 75 per cent. of aluminum, 4 per cent. copper and the balance is spelter, with about 1 per cent. of nickel.

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HARRY GOLDBERG.—I have had some experience with alloying 25 per cent. zinc and 3 per cent. copper. We found the tensile strength about 37,000 pounds. The only trouble with metal of that composition is that it is very brittle.

J. P. CARRITTE.—It is very stiff; fractures similarly to steel, and has very little elongation.

HARRY GOLDBERG.—Two-tenths of 1 per cent. elongation. There are other zinc aluminum alloys that have various degrees of elongation. As you increase the strength you decrease the elongation. A slight elongation is necessary in automobile practice because the metal has to withstand the jar.

J. P. CARRITTE.—It is very similar to any metal in that respect. The higher tensile strength you get the less ductile the metal is, except in the case of some special steels.

HARRY GOLDBERG.—I presume the pouring temperature is about as low as consistent.

J. P. CARRITTE.—Of course, pouring temperature is governed largely by the size and nature of the pattern, but the lower you can pour the metal the better results obtained.

HARRY GOLDBERG.—I verify Mr. Carritte's experience regarding the relation between the thickness of patterns and pouring temperature. From Mr. Cox's table it will be seen that aluminum alloys should be poured around 1,225° to get the best results. As a matter of fact, with most patterns you cannot go as low as that. I have just been down to Buffalo and seen some castings for the Pierce-Arrow Company, 3/32 of an inch in thickness. Those you have to pour around 1,600°. That does not mean, at all, that you get low results, because the sand chills the metal very rapidly and you get much more strength than you would imagine from hearing Mr. Cox's paper read.

I question whether re-heating aluminum makes the metal brittle. I have records of thousands of test bars, in which we used scrap in various amounts. We also melt in iron pots and find no bad effects whatever in case not very much scrap is used. According to the S. A. E. specifications for No. 12, 1.7 per cent. of impurities is allowed, of which not more than 0.2 per cent. shall be zinc and the rest carbon, iron, silicon and manganese; that gives a range in the iron content. Of course, too much iron makes the alloy brittle. I also think it is not necessary to melt with charcoal covering, because, as is pretty well known, aluminum oxidizes very readily; even with a charcoal covering the aluminum would take up the oxygen more readily than the carbon. It seems to me it is just going to expense and extra labor to use that charcoal. You also have to skin very clean to prevent charcoal from getting into the metal. The result of 44,000 lbs. tensile strength for the alloy, Mr. Carritte mentioned, I think cannot be compared with the other results that Mr. Cox gave from test bars cast in green sand, because, as Mr. Carritte said, you would likely get more rapid chilling in the first case.

J. P. CARRITTE.—Our experience is that when the aluminum comes to

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heat it should be drawn at once. If, for any reasons the molds are not ready, in the hurry of shop practice the heat is held back, we find that covering with rough charcoal prevents oxidization and we get better results in the pouring. I think it is a well-established foundry practice, in aluminum experience, that the less scrap you can use the better castings you will get. It is undoubtedly a fact that every time the metal is reheated or cooked it becomes less valuable and has less strength, and becomes more brittle.

HARRY GOLDBERG.—In that connection I have just about completed a series of experiments in melting with oxidizing and reducing flames. I will fully agree with Mr. Carritte that re-melting injures the metal if it is melted in an oxidizing flame. If you melt it in a reducing flame it does not seem to make any difference how many times you re-melt it. As far as I know there is no difference between the strength of the metal in bars in which the metal was melted in a reducing flame or in oxidizing flame. The only difference is in foundry practice, where it comes to the liability of the casting to crack.

C. H. TAYLOR.—I think you brought up the point of S. A. E. specifications. I would like to ask whether, in your opinion, it is not more important to keep the silicon and iron down quite a good deal than it is to keep the zinc down, in No. 12 mixture? In other words, are not silicon and iron the greatest enemies we have in aluminum.

J. P. CARRITTE.—Absolutely.

HARRY GOLDBERG.—They should be cut down more than the zinc, I think, although in view of the bad reputation of zinc alloys the S. A. E. committee, in making up that specification, tried to keep the zinc down as much as possible.

In view of the fact that the tests submitted by Mr. Cox show that zinc alloys are stronger, as long as no weakness shows up in the casting later in actual practice, I do not see why more zinc than that should not be allowed. Too much zinc in the No. 12 alloy will make it brittle. I think we had better set the S. A. E. laboratory at work to decide the merits of the zinc alloys. Zinc alloys are certainly stronger, and from Mr. Souther's results seem to stand up very well on vibratory and impact tests. It is simply a question of former results and actual tests and it would be a very good thing to have actual tests before we take any radical step.

J. P. CARRITTE.—We have found that the worst enemy of aluminum is the silicon and the iron; that it will even take up silicon out of a plate bar and the iron out of iron pots. We get very much better results by using a graphite-lined pot.

A MEMBER.—Will it not take the silicon out of a silicon pot?

J. P. CARRITTE.—Yes, it will.

C. E. COX.—Every one who has expressed himself seems to think that the aluminum-copper-zinc alloys are all right, but still the manufacturers are afraid of them. We want to find a method of demonstrating to the satisfaction of everyone concerned the relative merit of the two alloys.

VICE-CHAIRMAN MYERS.—It may take a little time, but it should be done.

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CONTRIBUTION BY MR. SOUTHER

HENRY SOUTHER.—I think that the broad statement that zinc and aluminum alloys are brittle is not warranted by the facts. The endurance tests that I made for the old A. L. A. M. Mechanical Branch indicate better endurance than the copper aluminum under exactly similar conditions. It is quite true that .35 zinc and .65 aluminum makes a brittle alloy. My own preference is about .81 aluminum, .15 zinc and .4 copper.

## ARE BAROMETRIC, TEMPERATURE AND HUMIDITY READINGS OF VALUE IN COMPARATIVE MOTOR TESTS?

FERDINAND JEHLE

(Junior Member of the Society)

The recording of atmospheric conditions on motor test data sheets seems, at present, to serve only to stop or open up a possible loop-hole; *i.e.*, if Mr. Jones' motor lost out in a competitive test with Mr. Smith's, the former gentleman will investigate the barometer, temperature and relative humidity readings. If he finds these to have been the same during both tests he generally goes home with his motor. If, however, he discovers that while his motor was tested, the barometer was ¼ inch lower than during the test of Mr. Smith's, he will at once attribute to that the difference in power, although it may be 10 per cent.

If the atmospheric conditions influence motor performance so greatly we should be able to reduce the motor output and efficiency to standard conditions. If the variation due to such causes is not less than about 3 per cent., we should be able by careful work to develop an empirical formula for doing this. That this formula would have to be empirical will no doubt be made clear by the following theoretical investigation which does not account for any such large difference.

BAROMETRIC CHANGES

*Difference in Compression.*—The power we get from an engine depends upon the compression pressure. The compression pressure varies with the initial pressure of the charge, all other conditions being the same.

Compression is calculated by this formula:

$$P_0 V_0^n = P_1 V_1^n \qquad (1)$$

or,

$$P_1 = P_0 \left(\frac{V_1}{V_0}\right)^n \qquad (2)$$

$P_0$ = Initial pressure.

$V_0$ = Initial volume.

$P_1$ = Final pressure.

$V_1$ = Final volume.

$\frac{V_1}{V_0}$ = Compression ratio.

$n$ = 1.31 (Constant used in table calculated by Cecil P. Poole, S. A. E. Data Sheets).

Let us see what the result would be on compression if the barometer were to fall from 30 inches to 29 inches. Supposing we have a motor

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with a compression ratio of 6, let us calculate the compression for a 30-inch and a 29-inch barometer reading. A 30-inch column of mercury is equal to a pressure of 14.72 pounds per square inch. Substituting in (2) we get

$$P_1 = 14.72 \times (6)^{1.31}$$
$$= 154 \text{ pounds per square inch (absolute).}$$

A 29-inch column of $Hg$ is equal to a pressure of 14.23 pounds per square inch. Substituting in the same formula we have

$$P_1 = 14.23 \times (6)^{1.31}$$
$$= 148.8 \text{ pounds per square inch (absolute).}$$

The ratio of the two compression pressures is this:

$$\frac{148.8}{154} = .966$$

which is the same as the ratio of barometric readings

$$\frac{29}{30} = .966$$

We may, therefore, say that the difference in compression is the same as the difference in barometric pressure, which in this case was 3.3 per cent.

*Change in Power due to Change in Compression Pressure.*—The only way that we can calculate the difference in power due to the difference in compression is to assume that the change in overall efficiency is the same as the change in cyclic efficiency. This is practically true.

$$E_c = 1 - \frac{1}{r^{n-1}} \qquad (3)$$

$E_c$ = Cyclic efficiency
$r$ = Compression ratio
$n = 1.31$
Using $r = 6$.

$$E_c = 1 - \frac{1}{(6)^{.31}} = .426$$

In the previous illustration we found that the compression dropped 3.3 per cent. This is equivalent to reducing the compression ratio

$$\sqrt[1.31]{3.3} = 2.5 \text{ per cent.}$$

The compression ratio is now equal to

$$6 - (6 \times .025) = 5.85$$

Substituting in (3)

$$E_c = \frac{1}{(5.85)^{.31}} = .422$$

The loss in cyclic efficiency and hence in overall efficiency due to the assumed change of barometric pressure is

$$\frac{.426 - .422}{.426} \times 100 = 0.94 \text{ per cent.}$$

*Changes in Power due to change in Mixture.*—Let us assume that at a barometric pressure of 30 inches $Hg$. we had a mixture of air and gasoline in the ratio of 15.36 to 1 by weight. This is the theoretical ratio, if we take the formula of gasoline to be that of Hexane

$$C_6H_{14}$$

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Now let us see what effect a drop of 1 inch in the barometer has upon this ratio. At 32 degrees Fahr., and at a barometric pressure of 30 inches 1 cubic foot of air weighs 0.0809 pound. At 32 degrees Fahr., and at a pressure of 29 inches it weighs 0.0782 pound,—3.3 per cent. less than at 30 inches. Then the ratio of air to gasoline (by weight) will be 14.85 to 1.

Let us assume that the exhaust gas at both barometric pressure contained no CO. Then 3.3 per cent. of the gasoline must have gone through without burning. The power is reduced an equal percentage.

Of course, the above assumption is not correct. The exhaust gas, when insufficient air is at hand, will contain CO, but we cannot tell how much. At any rate the loss could never be greater than the above. The maximum loss possible due to a barometer drop from 30 inches to 29 inches is therefore

$$3.3 + 0.94 = 4.24 \text{ per cent.}$$

### TEMPERATURE CHANGES

What effect a change of temperature has upon the performance of an internal combustion motor is even more difficult to determine than the effect of barometric changes. Changes in temperature affect only the mixture, provided the temperature is high enough to still vaporize the gasoline; 60 degrees Fahr., is, however, enough for that.

Let us assume that we have a mixture of air and gasoline in the ratio of 15.36 to 1. This is the theoretical ratio for complete combustion if Hexane ($C_6H_{14}$) is used. Let the temperature be 90 degrees Fahr. and the barometric pressure 30 inches. Now let the barometer stay constant and the temperature increase to 100 degrees Fahr. Air at 90 degrees Fahr. weighs 0.0722 and at 100 degrees, 0.0709 pound per cubic foot. The decrease is 1.8 per cent. The mixture ratio would then be reduced in the same proportion and be 14.73 to 1.

If we make the same assumption as before, that the combustion is complete as far as it goes, we shall waste 1.8 per cent. of gasoline and hence reduce the power by that amount.

### CHANGES IN RELATIVE HUMIDITY

Just what the effect on motor performance is if the relative humidity changes is impossible to determine. If the moisture in the air increases, the quantity of air (by weight) in a given amount of atmosphere is of course reduced and the power somewhat cut down. On the other hand, if we introduce water with the charge we may get a slightly better operation. In Bulletin 43 of the Bureau of Mines entitled "Comparative Fuel Values of Gasoline and Denatured Alcohol in Internal Combustion Engines" (by R. M. Strong and Lauson Stone), some results are given on the effect of spraying water into the cylinder with the charge. It was found that the compression could be greatly increased, in fact, to 140 pounds to the square inch, when the weights of gasoline and water were equal. Of course, with the increase of compression a small increase of power should be detected. Spraying water in with the charge without increasing the compression showed no change in power. Since it is impossible to change the compression of an automobile motor for every change of humidity of the atmosphere, we cannot gain any power from that source. The benefit derived from moisture in the air is therefore limited to the slightly better

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operation, due to the cooling effect of the water. That, however, must be very slight.

Let us take a practical illustration. The relative humidity is 70 per cent., say, at 90 degrees Fahr., and at a barometer of 30 inches. Then the weight of water vapor in a pound of atmosphere will be 10.353 grains or 0.00147 pound. We shall, therefore, reduce the ratio of air to gasoline 0.147 per cent. This is certainly negligible.

### CONCLUSION

Summing up the losses we have calculated, we have:

| | |
|---|---|
| Loss due to reduction of compression caused by drop in barometer from 30 inches to 29 inches | 0.94 per cent. |
| Loss due to incomplete combustion caused by drop in barometer from 30 inches to 29 inches | 3.3 per cent. |
| Loss due to incomplete combustion caused by a rise in temperature from 90 degrees Fahr. to 100 degrees Fahr. | 1.8 per cent. |
| Total | 6.04 per cent. |

Now, if we have a motor developing 50 H.P. when the barometer stands at 30 inches and the temperature is 90 degrees Fahr., at a barometer of 29 inches and temperature of 100 degrees Fahr. it will develop

$$50 - (50 \times .0604) = 46.98 \text{ H.P.}$$

Since we have assumed almost the extreme changes in atmospheric conditions, and also the maximum effects that they could cause, it seems that in practice no such great differences would be observed. In fact, we know that we have assumed too great a loss due to incomplete combustion. The only way in which we can arrive at a definite conclusion on this subject is to run special tests with that end in view. In cold rooms, in which motor tests can be run, we can control the temperature and possibly the humidity. The pressure of the entering air might be controlled with a small blower. Such tests would be of real value. They would show better than any calculation what differences atmospheric changes bring about. It seems that these differences would be smaller than our calculations indicate.

## DISCUSSION

F. H. Trego.—I have some actual figures taken from a motor test which we ran for 351 hours, at 1,200 r.p.m. The throttle was wired wide-open, and the spark fully advanced 35 degrees on the flywheel. The speed was maintained by regulating the torque. The ordinates of the upper curve are pounds pull. Observations were taken for humidity, barometric pressure and temperature, both wet bulb and dry. Unfortunately we did not take these readings until the motor had run about 180 hours. The barometric readings were taken at the beginning and end of ten-hour periods and averaged. We used the last barometric reading of a given period as the first one of the next period. From the dry bulb temperature and the barometric readings I figured the weight of air per cubic foot as shown and plotted the readings as ordinates of the lower curve. The pounds pull varied considerably in some cases. The only interesting

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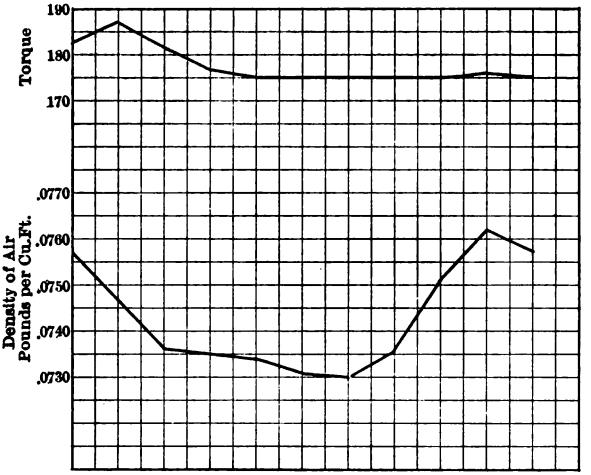


thing I can see in these curves is that the weight of air per cubic foot sagged considerably with the torque perfectly steady, and yet at another time there was a slight falling off in the torque, with a corresponding falling off in the weight of air per cubic foot.

Humidity is not figured in these results at all. The temperature varied from about 75 down to 64, or thereabouts, in the laboratory. The variation of the barometer was over an inch.

HERBERT CHASE.—Were those readings all taken at the same speed and the same water temperature?

F. H. TREGO.—Exactly the same speed. The water temperature was held at about 120.

F. JEHLE.—Those curves are of very great value as proving somewhat experimentally what I have been trying to express; that is, that the barometric changes are not nearly as important as we think they are. In one case, as the barometer fell, the power did not change at all. In another the weight of air went up very nearly to where it was at the beginning. The power went up slightly but not anywhere near where it was at the beginning. So even if the barometric conditions did cause changes, they were not large enough to be detected.

MR. PARKER.—Mr. Secor, whose engine is used by the Rumely Company, introduces water into the kerosene charge, not only to raise the combustion pressure, but as he claims it to give less loss to the jacket, from the water being converted into steam at the explosion temperature, getting the expansion out of it, and then recondensing at the lower temperature of the exhaust, which, he says, gives a more even average temperature during the working stroke, hence lowering the jacket losses. Just how practical that would be, I do not know, but theoretically it would work out.

CHAIRMAN BIRDSALL.—The engine is injection-fed. I saw Secor's engine at Stamford, Conn., years ago, running on kerosene. You could

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take the cylinder head off the engine at any time, and it and the piston would both be perfectly clean. The water injection and water feed were worked out by Capitaine, in Germany, a number of years ago. If you will get the articles on the Capitaine motor, in English *Engineering*, you will find a great deal of information in regard to feeding water along with the fuel.

MR. PARKER.—Would not the humidity have a great deal of effect?

CHAIRMAN BIRDSALL.—There is so little water in the air that it is almost inappreciable.

F. JEHLE.—The tests of Strong and Stone referred to in my paper, showed absolutely no increase of thermal efficiency at all, whether the compression were raised or not. With higher compression the capacity was increased very slightly. The Mietz & Weiss engines, of course, use water in with their charge. It is pumped in in the form of steam. It keeps down the temperature some, and the cylinder a little cleaner. They use the hot bulb, of course. I think it would help the operation; possibly it would prevent pre-ignition.

CHAIRMAN BIRDSALL.—I understand there has been a car running around Detroit all winter that has been feeding water with the gasoline.

P. S. TICE.—Mr. Chairman, is it not true that the chief effects of barometric pressure and humidity changes are experienced in the carbureter itself? Is that not the consensus of opinion among the members present?

F. H. TREGO.—I would be inclined to that point of view. You can notice the effect with changes in altitude.

P. S. TICE.—With a spring valve carbureter, we usually increase the spring tension as the altitude increases, and with a carbureter without air valves, we have usually to put a somewhat smaller throat on the jet. Has that not been your experience?

F. H. TREGO.—The experience I have had is very limited, but less gasoline, or in other words, more air seemed to be required.

P. S. TICE.—When the humidity is excessive, that is to say, around 80 per cent., there is apt to be a marked tendency towards loading, under certain conditions. Of course, if we pre-heat the air or jacket the carbureter, we may reduce the percentage of relative humidity, and we have not that effect. But if we run without pre-heating, or jacketing the carbureter, we get that tendency towards loading. Now it may be,—I am not quite clear as to the exact cause,—that the globules of moisture in the air form nucleuses around which the gasoline will collect. You know that in throwing very finely divided gasoline against a wall, it will immediately go together again, and show up in a considerable body. Then again we are, of course, dependent largely upon the heat contained in the air to vaporize the fuel, and if we have a considerable percentage of moisture present, we must have possibly a little more heat available to vaporize the fuel. But I think the little nucleus theory is pretty nearly right; that centers are formed around which the particles will gather, and consequently be more apt to be thrown out in the passages through the carbureter and manifold.

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F. JEHLE.—Did I understand you correctly to say that in high altitudes you increase the tension of the air spring?

P. S. TICE.—Yes.

F. JEHLE.—How do you explain that, when the atmosphere is lighter. You have less pressure on the valve.

P. S. TICE.—The barometric pressure is less. Therefore, we have to increase the pressure drop around the jet in order to eject the same quantity from the jet. In the higher altitude we require a lower pressure about the jet of the carbureter to get the same quantity of fuel out of the jet in a given time under a given set of conditions.

The coefficient of flow through the carbureter throat would be higher with the denser air. Immediately the air becomes more attenuated the coëfficient drops, and the pressure drop, due to a given engine's action, with a given size throat, would be less. Do you agree with me?

F. JEHLE.—Yes.

P. S. TICE.—That is the reason for the increased spring tension, or the use of a smaller throat.

W. R. MCCULLA.—In that connection, with the high-compression long-stroke motor, we made a very practical experiment during a 24-hour test. We found our average speed during the night was very much greater than we could get during the day; with wide-open throttle. In later tests in the day time, we took all the air into the carbureter through a long wire gauze screen, on which we had water dripping, and absolutely got four seconds faster in the mile. I never knew any scientific reason why we did, but I know we did. Other manufacturers are working along the same line and getting similar results. In the high altitude we used a wick-type carbureter, with every alternate wick saturated with water. We got the same results that the car had given before in hill-climbing in the lower country, everything being equal; we held everything down as close as we could.

HERBERT CHASE.—I am inclined to agree very much with Mr. Jehle in the conclusions he reached in his paper. I have an idea that the statement which you often hear made that a car will run better in the evening than it will in the daytime, for speed and hill climbing, and so forth, is in good part a psychological effect. I doubt very much if you get a considerable difference in the power with the change in relative humidity, although it is possible that a considerable quantity of water used in the charge may prevent pre-ignition, as when used with kerosene. With some of the kerosene carbureters they have on the traction motors in the West they use a considerable quantity of water injected with the fuel. At a meeting of the Metropolitan Section, at which we had a discussion on kerosene carbureters, Mr. Bennett, who has had a good deal of experience with those carbureters, stated that he had found it desirable to use just as little water as could be gotten along with; just enough to prevent pre-ignition. In some cases he found it desirable to use no water at all, getting the best results without any water, but if he could not prevent pre-ignition without the water, he used it.

H. L. CONNELL.—Mr. Chairman, we have all read for a long time differ-

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ent persons' theories of why a motor seemed to run better at night. In the past I have always agreed with Mr. Chase that it was a sort of illusion, but it seems to me Mr. McCulla's data are something positive on that, not a guess.

HERBERT CHASE.—It would have been interesting, it seems to me, to note those experiments in the laboratory; other variables could have been kept the same. The varying temperature of the air might have affected the temperature of the cooling water; that might have caused the change, possibly. Whether the power actually increased or not, of course I do not know, but I wonder if it is not possible that the driver himself would, for some reason which we are not able to state off-hand, make better speed at night than by day. In other words, does not the personal element of driving enter, where it would not enter on the dynamometer tests?

F. H. TREGO.—In the chart I showed the curve is horizontal over a period of 40 hours. Before this the chart showed over a hundred hours with a horizontal line like that, but I did not have the barometric readings, or anything to cover it.

C. E. COX.—It would be interesting to have readings at more frequent intervals, in order to get a curve of the power at different times of the day and night. That would check up the change due to the difference in the atmosphere at night.

F. JEHLE.—I have just one other point that I thought somebody else would bring up. In the laboratory tests you may notice a difference of power once in a while, and not know how to account for it; you may read the barometer and the wet and dry bulb thermometers. But do you not think that the condition of the air affects the performance? In running a test for several hours a little of the exhaust will get into the room, in fact, considerable, most of the time. Do you think that the air taken into the cylinder contains enough of the exhaust gas to give it an incomplete combustion? Have you investigated that?

W. R. MCCULLA.—We use a couple of pretty large ventilating fans to keep the rooms about the same temperature and keep the exhaust gas out.

HERBERT CHASE.—I do think that makes a difference in certain cases. Take, for example, a motor test I made recently in a rather small room. I did notice that once or twice when we opened the doors to get a little better ventilation, the power appeared to increase somewhat, which indicated that the clearer atmosphere would help the power slightly.

P. S. TICE.—I would like to suggest to Mr. Trego that he can get practically a perfect line on the effect in the carbureter if he keeps a correspondingly continuous record of the temperature of the mixture.

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# METROPOLITAN SECTION

## THE DESIRABLE NUMBER OF GEAR CHANGES

By P. S. Tice

(Member of the Society)

It appears that the best angle from which to attack the matter of the desirable number of gear changes is through a consideration of the things that make a change gear necessary. Such an approach will serve to arrange the factors and quantities upon which must depend the desirability, in any one car, of any one number of gear changes, as compared with any other number of different ratios. The subject was treated by the writer in *Motor* some years ago.

In the first place, the use of a gearset can be fairly considered an expedient employed solely for the purpose of evading the consequences of certain very serious limitations in the performance of the internal-combustion engine. This is but another way of saying that the internal-combustion engine possesses practically none of that quality known as flexibility—which quality is so marked and important a characteristic of the other power plants that are used in motor cars. In the sense in which the term is here used, flexibility can be defined as the ability to maintain practically the normal power output over the whole of the useful speed range.

With a power plant capable of such a performance, means are at hand to vary the turning moment, or torque, inversely with the speed. This result is approximated in the steam car engine through the ability of the operator to control the value of the mean effective cylinder pressures by retarding the point of cut-off to the cylinders, and through selective compounding. By these means not only can the mean cylinder pressures be made nearly equal to the boiler pressures—which are in turn capable of being raised to several times the normal value—but, when desired, these greater pressures can be applied to three or more times the normal piston area, through a change from compounding to direct application. The net result of this is that a car so fitted is capable of operating over the whole of the reasonable and desirable speed-grade range without a change in the driving relationship between engine-crank and wheel-shafts.

The performance of a car in which the engine is capable of delivering its normal power at all speeds of rotation is shown graphically by such a curve as that marked X Y, in Fig. 2, the ordinates of which represent car or engine speeds, and the abscissæ grade percentages. Such a performance as is represented by this curve may be taken as the highest attainable.

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As compared with this kind of performance, that of the internal-combustion engine presents very serious limitations.

At full load (the only condition that need be considered in this discussion), at the several engine speeds involved, the mean working pressures within the cylinders of an internal-combustion engine are incapable of being varied with the speed to produce this result. Obviously, with such comparative constancy of values of the m.e.p.'s the output of a gasoline engine varies with the speed. Of course, the mean effective pressure is really maintained at only a relatively constant value, considering the entire speed range, since aspiration and other losses cause a lowering of the value as a certain upper critical speed is approached, so that, at speeds above the critical one, the m.e.p. value lowers so rapidly with speed increases that the output falls below that at the critical speed. From this, it is apparent that through a certain limited range of speed below the critical or normal, the turning couple, or torque, of a gasoline engine increases with a reduction of speed.

Torque can be expressed in inch-pounds or foot-pounds, and is the product of the number of pounds pulled, as in a brake test, and the effective radius at which this pull is obtained. Brake-horsepower is an expression of the rate at which an engine is capable of doing the work of which the torque is a measure. Thus, the b.h.p. ($P$) can be written:

$$P = T \cdot \frac{2\pi N}{33{,}000}$$

$T$, the torque, being expressed in foot-pounds, and $N$ being the speed of the engine in revolutions per minute. From this we get

$$T = \frac{P}{N} \cdot \frac{33{,}000}{2\pi};$$

and it is seen that the torque or turning couple of the engine, at any speed, is proportional to $P/N$, the quotient of the r.p.m. value into the b.h.p. at that speed.

Now, as stated, the mean cylinder pressure falls off to below its maximum value as the critical, commonly called the normal, speed is approached; and, therefore, $P$ does not truly vary as $N$. For this reason the quotient $P/N$, the measure of $T$, must be greater at some speed below the normal or that at which the greatest power is developed. Likewise, since there are also losses in the m.e.p. at the very low speeds, maximum $T$ occurs at some engine speed intermediate between the very low and the normal speeds.

An inspection of the brake-horsepower curves of a number of representative engines shows that it is characteristic of the average engine, *with carbureter and other adjustments as made in the car,* to operate with its maximum m.e.p. at about 400 feet per minute piston speed, and at its normal power at about 1,200 feet per minute piston speed. On this basis is plotted the $P$ curve of Fig. 1 as being representative of the output characteristics of an average engine. From this curve of b.h.p.—r.p.m can be determined the torque characteristics of the engine as per the expression $T = P/N$. In the figure the maximum output is at the point designated $P$, at an r.p.m. rate $N$.

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Applying the graphic method of translating the horsepower-speed curve into one of torque-speed we get a curve as *D-F-G*, from which it is apparent that at speeds below that of maximum torque, that quantity suffers a very rapid falling off. In Fig. 1 $n$ represents the speed of maximum torque and $p$ the power of the engine at that speed.

For the present purpose the values $N$ and $n$, and $P$ and $p$, correspond-

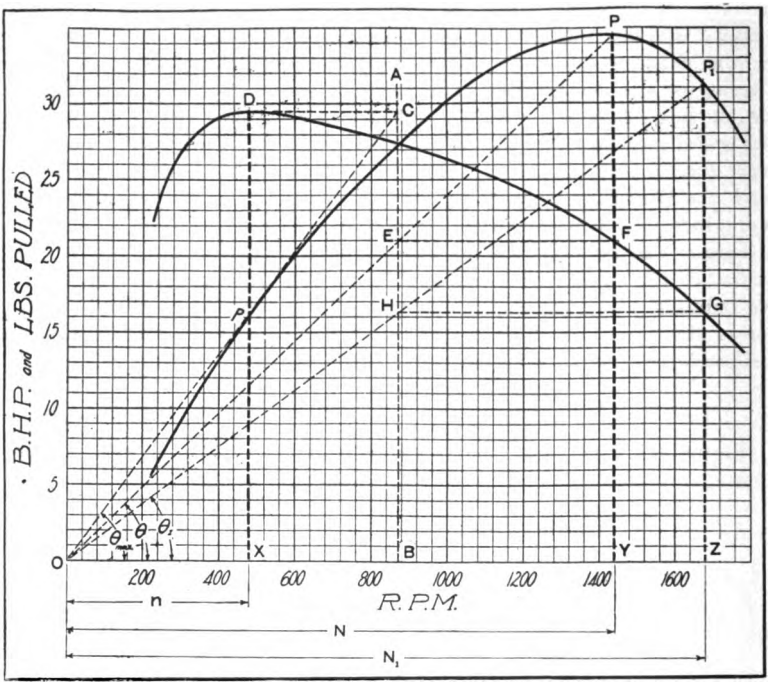


Fig. 1.—The graphic determination of the engine characteristics upon which the number and values of the change gear ratios must be based.

ing to them, respectively, are the ones of chief significance. $N$ is the r.p.m. rate at which the engine delivers its greatest output, and $n$ the speed at which it exerts its greatest torque.

Suppose a car to be running on "direct" or "high" with its engine speed $N$ and output $P$. Clearly the car will be running at its maximum possible speed. Suppose that the resistance increases, as through encounter with a positive grade. The car and engine speeds will automatically fall off to maintain balance between the tractive effort and the resistance. But, because of the increase in torque between speeds $N$ and $n$, the engine will be able to continue to propel the car on "high," so long as the resistance does not become great enough to reduce the engine speed below the value $n$. If the resistance does so increase, the torque falls off, and, if left to itself, the engine must stall. It is to prevent this that a change gear is used.

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It is clear from Fig. 1 that *the r.p.m. rates N and n are characteristics of the motor.* This being the case, they are absolutely independent of any gear ratios that may be employed between the engine crankshaft and driving-wheel shafts. Therefore, it follows that the ratio of the car speeds on *any gear* is equal to the ratio $N : n$. In other words, *the speed limits of a car on a given gear have a constant ratio, which is the same for all gears.*

In the foregoing it is assumed that the torque limit imposed itself to necessitate a change from a higher to a lower "gear." In the reverse

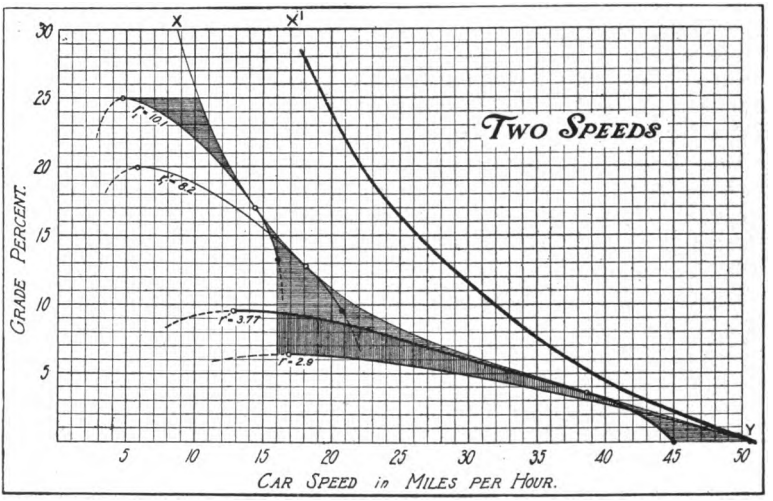


Fig. 2—Graphic representation of the "ability efficiency" of the hypothetical car when fitted with two forward "speeds."

procedure, if a car is started on its lowest or first "gear" on a level roadway, or on a light grade, the motor can easily and quickly be accelerated to its speed of maximum output $N$; and in order to prevent its racing a change must be made to a higher gear. The new gear ratio, the second, must be such that the torque demanded to overcome the resisting couple is within the capacity of the motor at its new speed. But it is clearly an object to have the maximum torque on the second gear no greater than necessary; that is, to have the reduction in the r.p.m. rate of the motor, in passing from first to second gear, as great as possible, since only in this way will the required change to the next higher gear be deferred the longest. Hence, in ascending, as in descending progression, it is the engine speed corresponding to the maximum torque that is fundamental.

As establishing the limitations of the internal-combustion car motor, let its performance in driving a car be compared with the performance represented by the curve X Y, of Fig. 2. Let it be remembered that the X Y curve represents the ideal condition.

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If our engine is capable of delivering a maximum power output equal to that of the hypothetical engine giving the X Y result, it is clear that a given car will be capable of the same maximum speed with either of them. Thus a curve representing the car performance with such an internal-combustion engine will coincide with, or more properly intersect, X Y at the point where the latter joins the abscissa of zero grade. The car will now be running on its top gear.

But since the power output falls off with the reduction in car speed that inevitably accompanies an encounter with a rising gradient, the curve of high gear performance will be divergent from X Y at an ever-increasing rate as the grade increases. But, as noted, the engine will be able to propel the car on that particular driving ratio until the increasing resistance of the grade reduces the engine speed to a value less than $n$. It will be found that this curve of speed-grade, on high gear, will fall with reference to X Y as that curve designated $r$.

For the time neglecting certain points of expediency in the matter of the ratio of the "high gear," and considering that the maximum speed of which the car is capable with its given engine equipment is desired, that ratio value will be selected which will make the engine speed of maximum output coincide with that car speed at which the sum of the resistances equals the motor's maximum output. The curve $r$, Fig. 2, represents the performance on such a ratio in a car of average specifications and average relationships of power, weight, windage area, etc.

Clearly, some other ratio must be included in the equipment to permit of negotiating the maximum road gradients, which are away beyond that within the capacity of the motor on the ratio $r$. If it is assumed that a certain maximum gradient must be allowed for, it is possible to complete the graph, Fig. 2, insofar as the two extremes of maximum speed and maximum grade are concerned. Selecting a ratio $r_1$, such that the assumed maximum gradient can be negotiated at the engine speed of maximum torque, we get a curve as that designated $r_1$. As before, this curve intersects the ideal X Y curve at the car speed at which the engine again operates at the speed at which it develops its maximum output. These curves of performance are based on the specifications of an average car—those summarized in the footnote on this page.* It will be noticed that in the graphs, Figs. 2, 3 and 4, each ratio curve bears three points, two of them open and one solid. The open points at the peaks of the curves locate the car speeds at which the motor is exerting its maxi-

*Car weighing complete, ready for the road, 2,650 pounds; the four passengers it is designed to carry weigh 600 pounds—a total $W$ of 3,250 pounds. The average modern car of this size will have, with its wind shield, a projected frontage area of some 15 square feet. Let it be assumed that the wheel diameter $D$ is 34 inches, and that the engine fitted in the chassis gives the power output shown in Fig. 1. Let $E$, the mechanical efficiency in "high" or "direct," be taken at the conservative value of 80 per cent., and $E_1 = E_2 = E_3$, etc., the efficiencies on the "gears" equal to 70 per cent. $K$, the coëfficient of tractive or road resistance, is .02 for macadam, on which surface we will suppose the car is to be run. The coëfficient of grade resistance $G$ is the decimal expression of the percentage of the grade (thus: A grade of 1 in 4 is one of 25 per cent., therefore $G = .25$; a grade of 1 in 10 is one of 10 per cent., and $G = .10$). We now have values assigned as follows:
$W = 3{,}250$ $p = 16.1$ $E = .80$ $A = .055\ V^2$
$D = 34$ $N = 1{,}440$ $E_1 = .70$ $G = \%/100$
$P = 34.6$ $n = 480$ $R = .02$ $V_1$, etc. = m.p.h.

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mum torque; the second set of open points indicate the car speeds on the several ratios at which the motor is delivering its maximum output, and therefore mark the points of performance coincident with the ideal X Y; and the solid points represent the performances if the motor is forced to a speed $N_1$, greater than $N$, as per Fig. 1.

It will be seen that the curves $r$ and $r_1$, of Fig. 2, do not include any of the same car speeds, over the range $n$ to $N$ in motor speed. This means that if this particular car is fitted with only these two changes of ratio a considerable loss in car speed will be experienced when it becomes necessary to change from the higher to the lower ratio; that is, unless the engine is unmercifully raced on the lower of the two. The areas in-

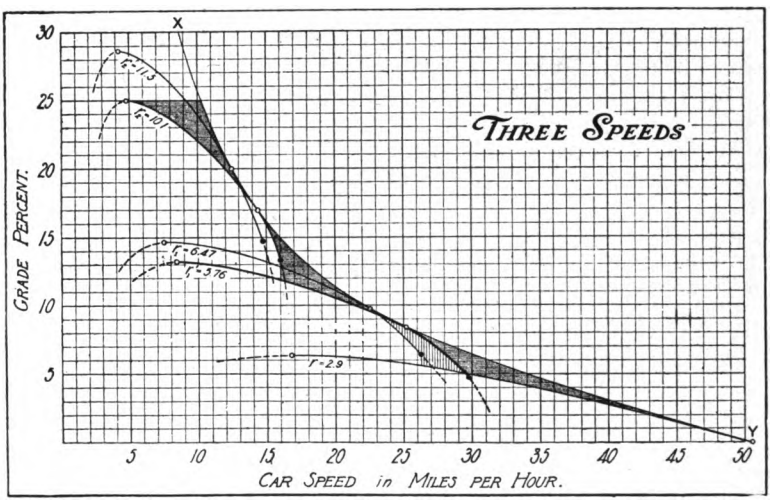


Fig. 3.—The ability losses in the same car when it is fitted with three properly selected forward gear changes.

cluded between the ratio curves and the X Y curve are measures of the loss in ability suffered.

Before noting the effects in this particular case of an increase in the number of ratios or gear changes, the certain points of expediency alluded to earlier may be taken up. The kind of service to which the car is put, and the topography of the country or section of country in which it is used, can be played upon to mitigate the obvious losses. Thus, if the country is flat and the roads uniformly good, a lesser maximum gradient need be allowed for. This will go far toward reducing the loss in what has been termed ability, as per such a ratio curve as $r'_1$. Then, again, if the country is hilly and the roads poor so that the maximum possible speed cannot ordinarily be attained, or can be attained only at foolish risk, a slight increase in the ratio of "high gear" may be made, with a relatively great corresponding reduction of ability loss all along the line of car speeds ordinarily employed in any section of any country. The

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nature of such an increase in the high gear ratio is shown by the curve $r'$, Fig. 2.

It is a peculiarity of this phase of car design that small sacrifices of the maximum speed on any gear ratio, whether it be on high, low or whatever, bring with them relatively great gains in ability at the lower speeds on the same ratio.

Furthermore, it is apparent that if the ratio of power to weight in the car is greater than that assumed in the calculations involved in this diagram, the X Y curve will become somewhat as X' Y, and grade-nego-

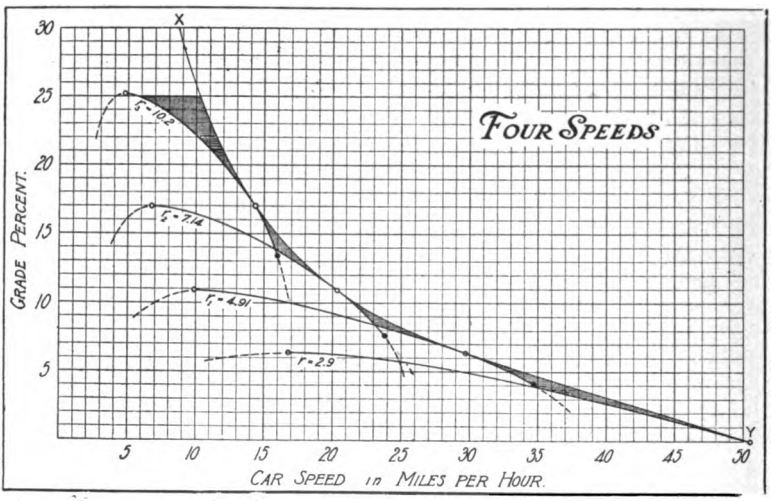


Fig. 4.—How the use of four forward "speeds" serves to minimize the "ability efficiency" losses in the hypothetical car.

tiating ability of the car on any of its gear ratios will be increased; and, conversely, if the ratio $r_1$ is selected to keep the maximum grade ability at the pre-selected value, it will be lower, and the speed-grade ability of the car will be greater. In any case, an increase in the power to weight ratio will increase the maximum grade-speed ability very much more rapidly than it will the maximum speed capacity on the level. This is because of the high rate of increase in wind resistance at the higher speeds, and the relative unimportance of mere car weight, as limiting maximum speed on the level.

The employment of a third ratio in the case in hand, intermediate between the $r$ and $r_1$ previously considered, will have the effect shown by the then $r_1$ curve of Fig. 3, the former $r_1$ curve becoming $r_2$. The use of this intermediate gives a considerable overlap in speeds at both ends of its range, and very effectually cuts down the losses in ability; reference to Fig. 3, as compared with Fig. 2, shows just how effectively in this particular case. The alternatives in intermediate gearing shown serve to point how the value of this ratio can be selected to minimize the ability

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loss at any desired point or through any desired intermediate range of grades and speeds.

It is very evident, in view of the effects of an increase in power to weight ratio in the car noted in the case of two ratios, that a lesser increase in this same direction will have a much greater and much more beneficial result with three ratios.

Four properly spaced ratios, two of them intermediate between those for maxima in speed and grade climbing, further cut the losses, as shown in Fig. 4. In fact, it appears that the limit has been reached, for all practical purposes. A slight increase in the power to weight ratio in this car would certainly make the use of more than one intermediate superfluous.

It is true that more gears would cut the losses still further in this case, but five or even six would not reduce them by the same amount, much less in the same proportion, that four have cut the losses of three. Then, again, it becomes increasingly difficult to select the best adapted gear ratio in the actual operation of a car when there are a great number of them. With more than four or five changes, in the average car, it is safe to say that we would begin to feel the need of an automatic device to shift them as grade and speed demanded.

One of the chiefly significant things demonstrated is the fact that a slight curtailment of the ability at the highest speed, with any one of the ratio values, causes a relatively very high proportionate gain through the lower part of that ratio range.

All of this has not answered the question: "What is the most desirable number of gear changes in a car?" That question cannot be answered in a direct manner, as by saying that four are more desirable than three, or that three are more desirable than two—although in average practice this latter comes very close to the fact.

The desirable number of gear changes depends in part on the ratio of power to weight, as has been shown; and the lower this ratio the greater the number of gear changes desirable. This matter most largely depends upon a factor which embraces the characteristics of the engine—the $N$, $n$, $P$ and $p$ of the foregoing.

It may be assumed, and is so taken in practice, that the output at $N$ revolutions is the maximum that the motor is capable of delivering. Let $V$ be the maximum velocity the car can attain at the engine speed $N$, its output at that speed being $P$. Then, if $R$ is the coefficient of tractive resistance per pound of car weight on the level, and $W$ is the weight in pounds of the car and its passengers, we have

$$P = V W R \qquad (1)$$

In the factor $R$, the mechanical efficiency of the mechanism between the engine crankshaft and the driving-wheels is assumed to be included, a further assumption being that it is constant for all gear ratios. This, of course, does not correspond with the facts; but for the purpose of illustration the discrepancy can be overlooked in the interests of simplicity in the analysis. Likewise, no account is taken of the air resistance, and for

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the same reason as above. Both these matters will be taken up later, and will be related as modifying the result, after the main considerations have been established.

The gear ratio $r$, corresponding to the speed $V$, is determinable when $V$ and $N$ are known. Supposing the car now to pass from the level onto a rising gradient, this ratio $r$ can be maintained in use so long as the grade resistance coëfficient $G$, an additive to the traction resistance coëfficient, does not create a demand for a tractive effort greater than the torque at $n$ revolutions. Now let $p$ be the motor output at $n$ revolutions, and $v$ the corresponding velocity of the car without change of driving ratio. Then $G$ must satisfy the equation

$$p = v\,W\,(R + G) \tag{2}$$

If the resistance due to the grade still increases, the gear must be changed, and it is natural to select a new ratio of such value as will permit of bringing the motor back to its normal output and to $N$ r.p.m. Therefore, after changing gears,

$$P = V_1\,W\,(R + G) \tag{3}$$

when $V_1$ is the new car speed corresponding on the new gear to $N$ revolutions of the engine. (The notation here and in the following is $V_{sub}$ and $v_{sub}$, for the maximum and minimum car speeds on the gear ratio which the *sub* denotes. Thus, $V$ is the maximum speed on the highest gear, $V_1$ the maximum on the next lower gear, and $V_2$ on the next lower, etc.)

From equations (2) and (3)

$$\frac{p}{P} = \frac{v}{V_1} \tag{4}$$

But it has been shown that $V$ and $v$, that is, $N$ and $n$, have a fixed ratio under all conditions of gear, for the same motor. Denoting this relationship $(N/n)$ by $K$, we have

$$v = \frac{V}{K};\quad v_1 = \frac{V_1}{K};\ \text{etc.};$$

and (4) can be written

$$\frac{Kp}{P} = \frac{V}{V_1} \tag{5}$$

In the same way as above, if $G_1$ is the grade coëfficient at which it again becomes necessary to change to a lower gear,

$$p = v_1\,W\,(R + G_1) \tag{2'}$$

$$P = V_2 W\,(R + G_1) \tag{3'}$$

and

$$\frac{p}{P} = \frac{v_1}{V_2} \tag{4'}$$

from which, as before,

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$$\frac{Kp}{P} = \frac{V_1}{V_2} \tag{5'}$$

Proceeding thus from gear to gear, we get

$$\frac{V}{V_1} = \frac{V_1}{V_2}, \text{ etc.}, = \frac{Kp}{P} = \eta \tag{6}$$

Therefore, on the assumptions made, the car velocities at $N$ r.p.m of the motor, and hence the successive gear ratios, form a geometrical progression of which the common ratio is

$$\eta = \frac{Kp}{P},$$

where $K$ is the ratio of the r.p.m. rate at maximum output to the r.p.m. rate at maximum torque, $p$ is the horsepower at maximum torque, and $P$ the maximum horsepower. The quantity $\eta$ is thus seen to be a very important characteristic of the motor. The greater its value the less need be the number of gears, or the less the necessity of shifting them.

There still remain to be considered the effects upon the ratios of progression of the gear changes, and upon the gear ratios themselves, of the efficiency of power transmission, between the engine crank and the driving-wheels, and of the resistance to the car's motion offered by the air. The efficiency of transmission, $E$, will naturally vary with the number of gear trains and other sources of loss involved on the different "gears." $E$ is included in the foregoing equations as a denominator of those members of the expressions to which $p$ and $P$ are equated.

The air resistance, expressed in pounds, is additive to the resistances due to traction and to grade, and is expressed

$$A = .0017\, a\, s^2,$$

$a$ being the effective forwardly projected area of the car in square-feet and $s$ its speed in feet per second. In terms of miles per hour $s$ becomes $1.466\, V$; and the air resistance is expressed

$$A = .0037\, a\, V^2,$$

designating the term $.0037\, a$, which is constant for any one car, as $\rho$, and taking account of mechanical efficiency losses and air resistance, the equations, as (1), can be written in the complete form

$$P = \frac{V\,(W\,R + \rho\,V^2)}{E} \tag{7}$$

It will be noted that that portion of the total resistance attributable to air resistance varies at $V^2$, while the other factors vary directly as $V$. From this it is obvious that increments of car speed induce relatively much higher resistances at the higher speeds than at the lower.

The results so far suffice to determine the number and values of the gear ratios if the weight of the car, its effective wind resistance-area, the maximum grade to be allowed for, and its motor's characteristics are known. Including these factors in the equation representing the limiting conditions of speed and grade, it is possible to evolve an equation for the

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desirable number of gear changes, which will embrace all of the conditions, and therefore prove of practical value. Thus, at maximum speed on the level we have the balance of power and resistance indicated in (7); and at the maximum grade allowed for

$$p = \frac{v_n W (R + G_{max})}{E_1} \tag{8}$$

$E$ and $E_1$ being the respective mechanical efficiencies of transmission on direct and on the "gears."

From what has gone before, the speed of negotiation of the maximum grade $v_n = V_n/K$, and $V_n = V/\eta^a$, $\eta$ being the factor resulting from a combination of engine characteristics, and $a$ being the number of gear changes. From this last it is seen that $v_n = V/K\eta^a$.

Substituting this value in equation (8)

$$\frac{V}{K\eta^a} \cdot \frac{W (R + G_{max})}{E_1} \tag{8'}$$

Setting equation (7) over (8') we get

$$\frac{P}{p} = \frac{E_1 (V W R + \rho V^3) K \eta^a}{E [V W (R + G_{max})]}$$

and

$$\eta^a = \frac{P E [V W (R + G_{max})]}{K p E_1 (V W R + \rho V^3)}$$

from which the desirable number of gear changes is

$$a = \frac{\log P E [V W (R + G_{max})] - \log K p E_1 (V W R + \rho V^3)}{\log \eta} \tag{10}$$

This equation is somewhat cumberous, but the result is interesting. It serves to present most clearly the great importance of the engine characteristic $\eta$, since from its position in (10) it appears that the number of gear changes necessary is in inverse proportion to its value.

Substituting in equation (10) the car and engine specifications of the footnote in the foregoing, and which were used in working out the graphs of Figs. 2, 3 and 4, we have

$$a = \frac{6.088845 - 5.545060}{0.146128}$$

$$= 3.73,$$

or, in the necessary round number, four — the desirable number of gear changes.

## CHASSIS TESTING APPARATUS

P. P. DEAN

(Member of the Society)

The commercial testing of the finished chassis whereby accurate measurements may be taken seems to have received very little attention in this country, many engineers being of the opinion that it is unnecessary

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to keep any records of performances along these lines or take any such measurements. It is claimed by some that a good road test cannot be improved upon, such a trial providing all conditions that a car in actual use will meet, but I believe that the time has come to look more closely into this claim, from both technical and commercial standpoints. Scientific testing in factory laboratories and institutions necessitates, of course, the use of a dynamometer. The question is whether this machine can be used to commercial advantage in works turning out quantities of cars daily. Nearly all the companies are interested keenly, and a number are already using the stationary method, while many more are experimenting along the same lines.

### ADVANTAGES

Whereas the majority of engineers admit the stationary test (supplemented, of course, by a short road run) to be ideal, they claim that the price of a good rear-wheel equipment impedes adopting it in sufficient quantity to eliminate road testing altogether. There is not to my knowledge a single company offering at a reasonable price a really good and complete commercial equipment for rear-wheel testing. But few opinions on this subject having been voiced, and there being available hardly any information for dynamometer manufacturers to work upon, I present the following points in the hope of creating discussion of value in designing a standard, reasonably priced outfit. The advantages claimed for stationary over road testing are:—

1. Actual measurement of horsepower at rear wheels. Loss in drive from wheels to brake is negligible and cannot be readily separated.
2. Speed in miles per hour at any load may be measured; also revolutions of engine.
3. The chassis may be loaded to its maximum capacity in both horsepower and speed, a limit of say 70 m.p.h. being established on account of the speed of the driving chains.
4. The maximum power available may be absorbed through first, second, third, fourth or reverse gear, through any length of time.
5. Operation of transmission gear may be noted under full load as to noise, lubrication, ease of shift, etc.
6. The slightest increase or decrease in power developed by carbureter adjustment, may be noted easily on the horsepower-meter while running. This also applies to spark setting, and is important.
7. Actual effect of muffler cut-out.
8. Actual load, speed and time of test limited only by the ability of the reciprocating parts to stand the strain.
9. No abnormal road speed necessary; therefore possibility of speed fine eliminated.
10. One operator can test four or five chassis at once and keep accurate record of every measurement.
11. Actual consumption of gasoline under any condition may be ascertained.
12. No tire expense.
13. Every important part except springs may be watched under full

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load conditions. Complete record on file for reference or prospective purchaser.

The above-mentioned observations may be made when using an electric cradle dynamometer, some modification being necessary in the event of a water brake being used to absorb the power.

Now that some of the many possible measurements and facts which can be actually ascertained have been enumerated, the question arises of just how much of this information is really required. In view of the fact that the road test has been used continually since the beginning of the industry, it seems hardly probable that engineers will sink a large sum in testing stands unless confident of a substantial saving or gain in another direction.

## COST

If stationary tests are to be adopted in place of the usual road trials, at least a dozen equipments would have to be installed, depending, of course, upon the factory output. The first cost of the installation is accordingly considerable. The kind of apparatus would depend upon the accuracy of the measurements required; i.e., if actual rear-wheel horsepower is desired either an electric or hydraulic dynamometer is required, and even then the driving chain loss cannot be separated readily. If an approximate power only is necessary a plain electric generator may be used in conjunction with a set of efficiency curves, corresponding to say five separate speeds in m.p.h. with four loads for each speed. Within 5 to 10 per cent. of correct horsepower can be measured with this machine, the readings being noted on a wattmeter calibrated in horsepower if desirable, this horsepower instrument showing particularly the value of carbureter and spark adjustments. With this or the electric dynamometer the energy has to be dissipated through some form of resistance and cannot be directed back into the supply circuit satisfactorily.

The water dynamometer measures the actual horsepower, including chain-drive loss, but usually has to be controlled by valves fitted on the machine itself, and, therefore, not near the steering wheel of the chassis under test. Observations with altered carbureter and spark settings cannot be noted readily without first converting torque and speed readings to horsepower.

The electric cradle dynamometer is, of course, the ideal machine to use, but for commercial chassis testing I believe its cost will be prohibitive when used in large quantities.

A fair comparison of cost of a single equipment designed to take care of 50 horsepower at rear wheels is as follows:

| | |
|---|---|
| Hydraulic Dynamometer | $750.00 |
| Dynamo | 900.00 |
| Electric Dynamometer | 1,400.00 |

including all speedometers, measuring instruments and chains, but without stands and universal joints. Against this first cost recognition has to be taken of the saving of time and tires, quality of results, and facilities for observation not possible while the car is in motion.

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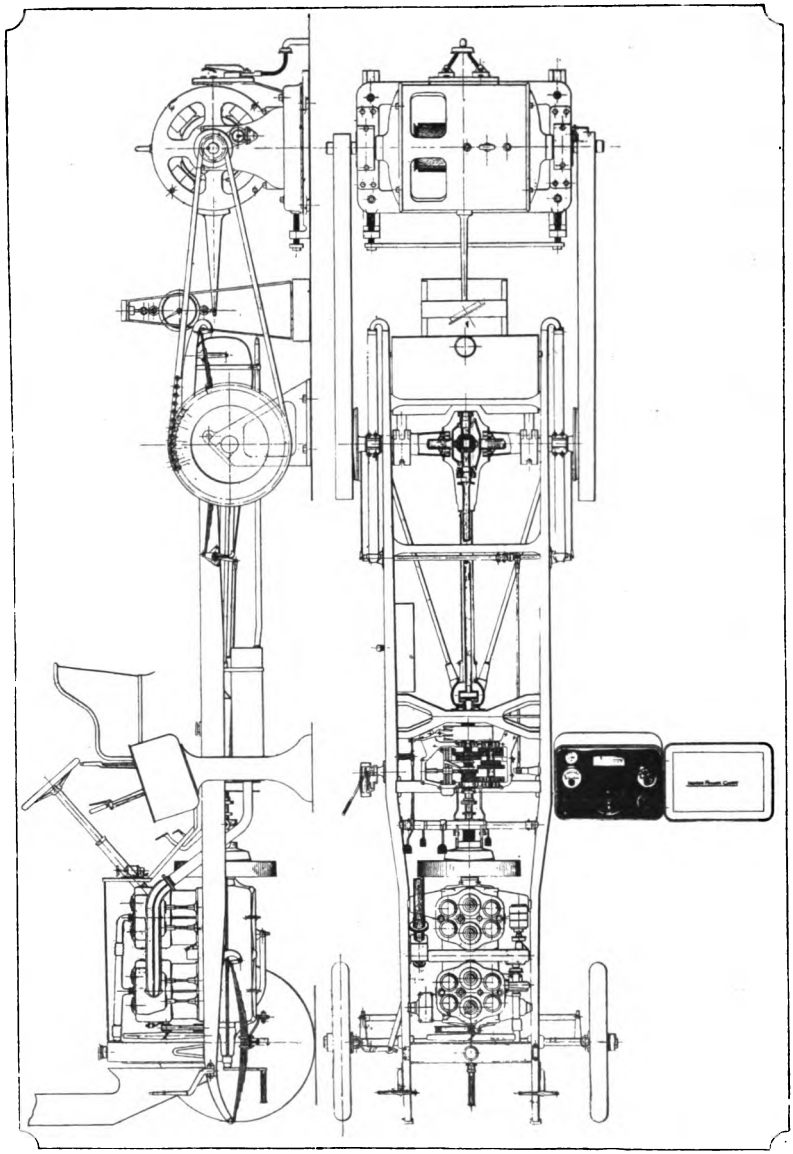

Fig. 1—Dean Chassis Testing Dynamometer

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Fig. 1 shows a complete layout, with chassis, driving chains and electric dynamometer in place. The load-absorbing dynamometer (Fig. 6) is of the Diehl electric cradle type, dissipating electrical energy through a grid resistance. The particular size shown is capable of taking care of any normal standard chassis, and provides continuous braking power equal to 50 horsepower at the wheels, at a speed equal to 60 miles per hour, the limiting factor, however, being the speed of the driving chains.

Fig. 2 shows a test stand designed to accommodate cars using the full floating axle, slight modifications only being necessary, in order to accommodate other types of axles. Before the complete chassis leaves

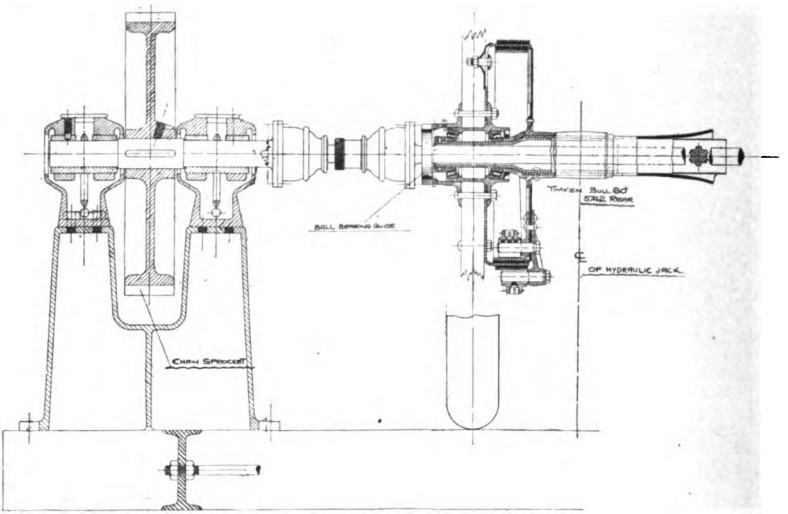


Fig. 2—Test Stand for Full Floating Rear Axle

the erection shop two dummy test axles are inserted through the housing and into the differential, the opposite end being provided with a flange for attaching to universal joint. Fitted to each of these axles is a ball-bearing guide in which the axle runs, the outer shell of the bearing fitting into the driving jaw clutch of the wheel. The stands each contain a pair of oil ring bearings supporting a shaft carrying the ninety-tooth chain wheel; the base of each stand having four lugs, through which holding down bolts pass to girders let into concrete. The two large chain sprockets, when once accurately lined up with the dynamometer pinions, need not be altered, so always insuring the proper working of the differential gear. It is noticed that the axles merely exert turning effort, the same as when in actual operation, and take no driving strain of the chains. The driving medium is universal joints.

The chassis is backed into place, the position being fixed by the axle housing coming into contact with a back stop, after which it is locked in place. With cars using full floating axle only, it has been found unnec-

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essary to jack up the chassis so that the wheels leave the ground. To provide for radiator cooling, a motor-driven centrifugal blower is used, supplying air through a duct terminating in a flared outlet covering the front of the radiator. By adjusting the speed of the motor a velocity equalling the speed in m.p.h. can be maintained. The power consumed by the motor forms part of the dynamometer load.

Now that the chassis is ready for operation, attention is first directed to the engine, which is set running by its own starter or cranked over. The clutch is released and the operation under no load noted but not recorded on the log sheet, unless it is desired to call attention to some particular points.

To control the loading of the chassis a master-control panel may be used, consisting of a slate switchboard mounted in a cast-iron pedestal box as shown. This box has a hinged cover and support for same, serving the double purpose of protecting the expensive measuring instruments and acting as a support for the horsepower conversion chart and log sheet. The face of the board (shown in Fig. 3) contains an electric speedometer reading miles per hour, calibrated to suit different wheel diameters, a similar instrument showing revolutions per minute on the dynamometer, a horsepower meter, a load-varying rheostat, and a load switch. The electric speedometer is particularly useful for this purpose, as the distance apart and respective location of magneto and instrument are immaterial. To provide a minimum load the small load switch is turned, which closes the automatic solenoid switch mounted on the dynamometer base, so connecting the load-absorbing resistance across the

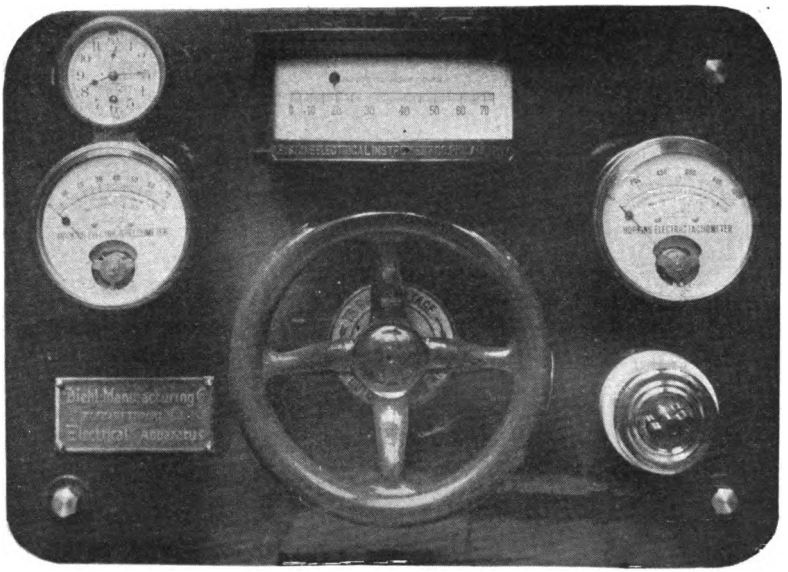

Fig 3—Master Control Panel

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dynamometer terminals. A mere turn of the large handwheel on the panel varies the brake power on the rear wheels from zero to maximum capacity of the car, so that it may be loaded and tested at will at either gear position and through any length of time desired.

### OBSERVATIONS

After the chassis has been adjusted to any given load, the testing operator can examine every part under working conditions, and observe the best possible carbureter and spark setting for different speeds, action of transmission gearing, lubrication of same, ease and quietness of running gears and differential, effect of muffler and cutout, temperature of cooling water, temperature of exhaust, consumption of fuel, and many other points. The horsepower meter does not show the actual power delivered by the rear wheels, but shows at a glance whether the power is increased or decreased by various adjustments, which is a very important factor. For actual horsepower measurements the weight shown on the scales at various speeds must be recorded under the column "W," and afterward converted by the aid of the chart to horsepower.

For fuel-consumption tests a fuel-measuring device (Fig. 4) must be provided, one type of which is described below:

Gasoline is supplied from a 50-gallon tank mounted on a portable stand, forming part of a fuel-weighing recorder, so arranged as to show the exact time in which one pound of fuel is consumed, together with the exact number of revolutions of the rear wheels or miles made by the chassis in that time. The copper tank rests on sensitive platform scales of the double-beam suspension type, divided into tenths of a pound, a flexible supply pipe being carried to the carbureter. Mounted on a slate panel is a telegraph relay and transmitter connected mechanically to a split-second-return stopwatch, while geared to the dynamometer shaft is a Veeder revolution counter thrown into and out of gear magnetically. The operation is as follows:

When the chassis is operating under any given load the sliding poise on the scale-beam is set so that it almost floats, but remains in the upper position. As soon as the engine has consumed enough fuel to decrease the weight, the beam falls and the poise is set at one pound less, when the beam rises again. As the beam drops, however, it strikes the transmitter contact of the relay, which automatically starts the stopwatch and also throws into gear the counter on the dynamometer. As soon as a pound of fuel has been consumed the scale-beam again falls and through the relay disengages the gears on the counter and stops the watch, thus recording accurately the exact time consumed and the number of revolutions of the rear wheels in which one pound of gasoline is used. A complete record of performance throughout the test may be kept in the form shown in Fig. 5.

I believe that while the above-described equipment embodies every feature necessary for a sound chassis test, it is nevertheless too expensive to be installed in quantity, costing complete approximately $1,400. Until we hear more from the car designers as to their actual requirements no standard medium-priced equipment can be offered.

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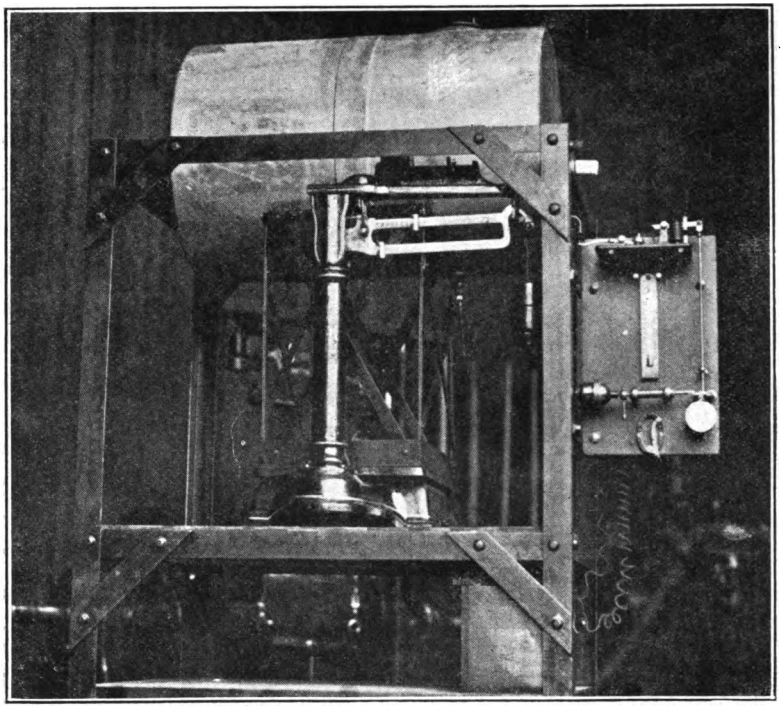

Fig. 4—Fuel Measuring Device

MODEL WINDEMERE MOTORS LTD. CHASSIS NO.

| LOW GEAR | | | | INTER GEAR | | | | THIRD GEAR | | | | HIGH GEAR | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| R.P.M. | M.P.H. | W. | B.H.P. | R.P.M. | M.P.H. | W. | B.H.P. | R.P.M. | M.P.H. | W. | B.H.P. | R.P.M. | M.P.H. | W. | B.H.P. |
| | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | |
| START | | | | START | | | | START | | | | START | | | |
| STOP | | | | STOP | | | | STOP | | | | STOP | | | |

| REVERSE GEAR | | | | OBSERVATIONS |
|---|---|---|---|---|
| | | | | |
| | | | | |
| | | | | |
| START | | | | |
| STOP | | | | |

TESTED BY
DATE

Fig. 5—Test Sheet

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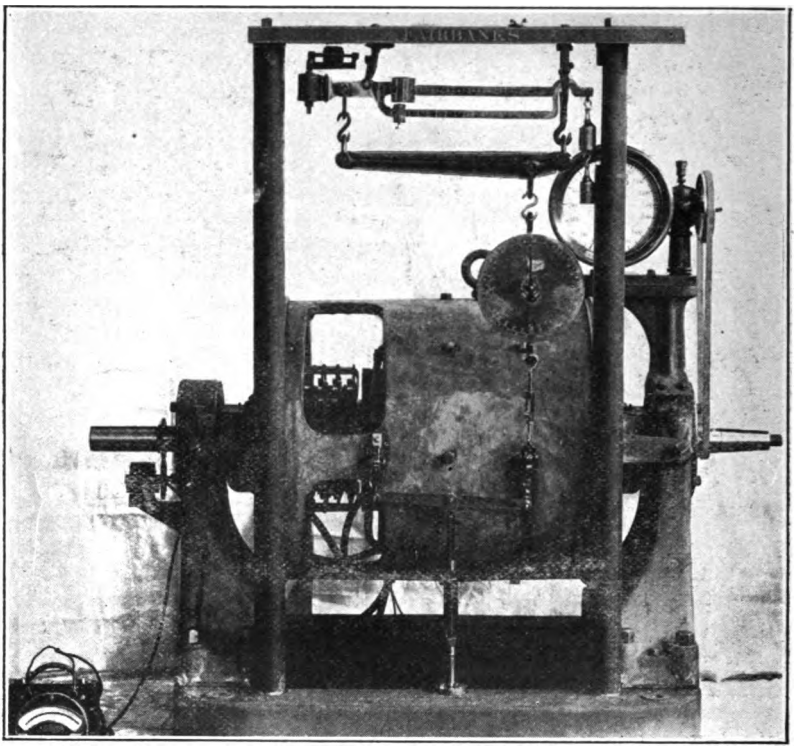

Fig. 6—Diehl Electric Cradle Dynamometer

## DISCUSSION

M. R. MACHOL:—Is the object of this equipment to eliminate entirely the necessity for road testing?

P. P. DEAN:—No, it is proposed to bring cars directly from the erecting shop and test them as indicated and then give them say a forty- or fifty-mile test on a very heavy road. This equipment will test everything except the springs and brakes.

M. R. MACHOL:—Does that test the differential at all?

P. P. DEAN:—You test that on the road.

M. R. MACHOL:—The engine is not running under a twisting force on the dynamometer.

P. P. DEAN:—No, it is as rigid as the chassis allows.

M. R. MACHOL:—A chassis might test perfectly on the dynamometer and on the road the twisting cause the heating of the engine and bearings.

P. P. DEAN:—I would like to leave that for further discussion. This equipment has not been designed with the idea of testing everything. It

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has been designed with the idea of saving testing and tire expense and eliminating as much as possible the usual road tests.

M. R. MACHOL:—Is the installation of this apparatus going to save any reasonable part of the road test that is ordinarily given to a car?

CHAIRMAN ANGLADA:—I think it is quite logical to assume that it would. You will be able to make all adjustments of gear shifting, carbureter and ignition and possibly the bevel-gear with that apparatus. Of course the testing of riding qualities will have to be done on the road.

R. W. KNOWLES:—Is it intended, in a large output of cars, to test 1 per cent., perhaps, on the road, for all these various points that have been brought out and then use the stand test, as a comparison, for the other 99 per cent. That is, you test out the fundamental principles of your cars on 1 per cent. and then the transmission and gears and wheels, and so forth, you test out on a comparative basis on this stand?

P. P. DEAN:—The idea of this equipment is to test every car. I think the chassis should be given a complete test on the stand and then go over fifty miles of heavy road with hillocks and mounds.

M. R. MACHOL:—If that generator be tested once on the basis of electrical output, why is there need for any further test?

P. P. DEAN:—As I said, it is accurate only between 3 and 10 per cent.

R. W. KNOWLES:—The generator will not deliver a constant output?

P. P. DEAN:—It will, but you have to calibrate it closely. The efficiency of the machine in the first place depends upon load and speed.

A. F. MASURY:—I would like to ask what advantage this dynamometer has over the transmission dynamometer that is put in line shaft in some place. You can buy those for about $200.

P. P. DEAN:—With the transmission dynamometer you have to do a lot of calibrating before you arrive at actual horsepower. Do you know of a good transmission dynamometer for this purpose; one that can be read while a car is in motion over rough roads? I think that if we could find a good transmission dynamometer we should be glad to consider it, especially if it is going to cheapen the testing equipments. One of the best transmission dynamometers is made abroad, in Schauffhausen, Switzerland; it costs practically $400 or $500 in this country. The principal reason you cannot use this type is that you have nothing to absorb the power; it merely measures the power.

A. F. MASURY:—You do not have to run the car on the stand test and then run it on the road; you have a gage set movably on the dash, and also a recording gage like a water meter. It is not any more bother than putting on the rear wheels.

P. P. DEAN:—Is it fitted into the driving shaft?

A. F. MASURY:—It can be anywhere where a universal joint may be used.

P. P. DEAN:—Will the gage read satisfactorily when going over jolts?

HERBERT CHASE:—The dynamometer which Mr. Masury speaks about is, I think, the Kenerson, which was described in a paper which I delivered about two or three months ago.* The idea of that dynamometer is that it can be applied under actual load conditions, and, of course, it may

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be applied in a motor car test if desirable. But the idea of the dynamometer described by Mr. Dean is to do away as far as possible, as I understand it, with a part of the road testing.

CHAIRMAN ANGLADA:—The small hamlets in the vicinity of Detroit are thinking of enacting legislation to prevent test cars going through them at high speed. The road testing of cars in Detroit is becoming a very serious matter.

A. L. MCMURTRY:—It seems to me that the drawbacks of the torsion type of dynamometer are many. With the type under discussion you can stand beside the car and get a rate of speed of sixty miles an hour and hold a fixed condition for a definite period, whereas with the torsion dynamometer the period for which you can hold a fixed condition is according to the condition of the road. In other words, the success of the torsion dynamometer at high speeds depends entirely on the road that you are traveling.

A. F. MASURY:—Is not the real argument to combat that you test the real rate that you are building for, and that you should always be able to test it over a given type of road also?

A. L. MCMURTRY:—In riding in a car at sixty miles an hour it is impossible to make carbureter adjustments. If you run it sixty miles an hour before making this test, and know the carbureter and throttle control at that speed, or whatever speed the car reaches, you can then hold this dynamometer at that speed; if you allow it to go above it you get a false condition; you get a speed higher than the motor is powerful enough to drive the car on the road; that is one of the important points of this type of dynamometer.

A. F. MASURY:—Can you not get these same readings from the engine itself, testing the position of the spark and throttle and carbureter adjustments? They can all be taken from the usual tests that you make on any engine, without going through with all this recording back to your dynamometer.

P. P. DEAN:—Continuing, you get every test except the twisting test of the chassis. Whether the clutch is going to operate properly when the various members of the chassis are operating in different planes, as they would do when one wheel is up in the air and the other down, is a test we cannot make on the stand and I think nobody wants to make it there.

N. B. POPE:—It seems to me that this device is essentially fitted for tuning up and standardizing the work. It will not give results comparable directly with those on the road, for various reasons. The play of the wheels constantly gives work to the joints of the propeller-shaft, and that absorbs a certain amount of power, which perhaps is very slight, but not negligible under some circumstances. It seems to me the apparatus is essential for tuning up. As a commercial device for use by the manufacturer who desires to compare the performances of different chassis in rapid succession it is, perhaps, more elaborate than the requirements

*S. A. E. 1913 Transactions, Vol. 8, Part I, page 225.

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would really justify. Of course, as a device for studying the properties of the power plant of the car, it is perhaps incomparable.

P. P. DEAN:—It was really not designed so much for that as to eliminate the continual running of three or four hundred cars on the road.

MR. CORBIN:—Has any means been taken for strapping down the rear axle relative to the springs? If not, the position of the bevel gear with reference to the universal joint would be very different from what it would in running. You have to strap the rear axle to a position where it would be doing ordinary work.

P. P. DEAN:—The chassis are usually loaded with a heavy bar of iron.

PROF. W. C. MARSHALL:—I would like to ask, Mr. Dean, if you make a correction for miles per hour, for wind resistance?

P. P. DEAN:—No, we have not yet taken that into consideration.

PROF. W. C. MARSHALL:—If you made a test on the basis of miles per hour and then went out on the road, you would not come within any reasonable distance of it.

P. P. DEAN:—How much difference do you think, Professor?

PROF. W. C. MARSHALL:—Well, 30 per cent. At twenty miles per hour it would not amount to anything at all. When you get up to sixty miles per hour it would be very material.

P. P. DEAN:—Well, of course, if we have to go into such fine points as that we shall have to design an equipment so universal that it will take an expert to operate it. The object of this apparatus is to put four or five cars on the stand and let one man take care of them during a purely commercial test.

N. B. POPE:—I would like to ask whether that apparatus would be sufficiently sensitive to record probable differences in loss between one low-speed gear and another low-speed gear in two chassis, for instance?

P. P. DEAN:—Yes, it would. You can get down within a fraction of a horsepower.

N. B. POPE:—That fraction of a horsepower would represent a considerable variation between two sets of gears.

P. P. DEAN:—I showed a slide a few minutes ago, representing a sample test-record blank. I would like to have an expression of opinion as to whether the preserving of such records would be necessary.

N. B. POPE:—I do not see why it should be necessary to preserve throughout a whole series of a hundred or a thousand chassis, the relation between low, intermediate and high gears. The performance of the motor, the powerplant, throughout the range corresponding to the usual string of observations such as you would get on the stand, I think would be sufficient.

P. P. DEAN:—On a road test there is not a single record or single figure taken, and that method seems to have been satisfactory, that is, as far as the operation of the car is concerned.

N. B. POPE:—It has had to be satisfactory.

R. W. KNOWLES:—Would it not work out something like this: If a factory took out fifty cars on the road and those turned out satisfactorily

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and were all put on this testing apparatus and each yielded a certain horsepower resistance, and another fifty cars each gave some other factors, under the same conditions there would be 90 per cent. of probability that they would turn out satisfactorily on the road? In other words, would you not have an opportunity of eliminating all the road tests until you had gotten to the final, and then go out on the road with this fifty-mile run?

P. P. DEAN:—If they tested favorably on the stand the chances would be very high that they would test favorably on the road. I do not see how we can make a direct comparison between the road test and the stand test. The only notification of trouble you have on the road is by something giving way.

R. W. KNOWLES:—The only thing we can do on the testing floor is to make a theoretical test from the rear wheels and so forth. When we get a good test on the floor we get a good one on the road, ninety times out of a hundred; when we get a bad one on the floor we get a bad one on the road.

P. P. DEAN:—In this case they would be very careful, and it is just a question whether the operator on the road would report any trouble or not.

Q. TWACHTMAN:—I would like to ask about the strains on the universal joints, and so forth. In going over bumps the rear wheels would jump off the ground. Do you notice that in going over irregular ground the transmission will very often race? Do you take a record of these strains?

P. P. DEAN:—No, we cannot take a record of them. If you desire such observations there are a thousand things to take into account, which require a very scientific apparatus. This is a commercial proposition only.

M. R. MACHOL:—If you are figuring on the revolutions of the engine or of the wheels on this test stand, and you get up to high speeds, forty to sixty miles an hour, is not the slippage of the wheels on the road going to be a very large factor?

P. P. DEAN:—I presume it would be, but with this outfit I do not see that there would be any slippage at all.

M. R. MACHOL:—You may be fooling yourself in believing you are running sixty miles an hour, whereas on the road at the same engine speed you would not get over forty or fifty.

P. P. DEAN:—Do you think there is that much slippage?

M. R. MACHOL:—There is on a wet day.

HERBERT CHASE:—Thirty per cent, that is. I doubt whether there would be that much.

M. R. MACHOL:—We have that much, pretty nearly, with a heavy truck.

CHAIRMAN ANGLADA:—To show how unimportant the matter of tire slip is, I will read from page 23 of Vol. I of S. A. E. data sheets: Three-tenths of one per cent. at forty miles per hour; six-tenths of 1 per cent. at fifty miles per hour; 1.1 per cent. at sixty miles an hour;

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1.8 at seventy miles an hour; 3.7 at eighty miles an hour; 5.4 at ninety miles an hour. These figures have been derived from tests on Brooklands Track.

P. P. DEAN:—I believe that Brooklands Track is of vitrified brick, too.

MR. COLBY:—No, it is concrete. It is a very, very bad surface. I have been all over it.

MR. PERRY:—I think the main question is why the manufacturers road-test cars? Do they test them to get the horsepower or to have them run smoothly, without noise and flexibly?

P. P. DEAN:—That is the point I want to bring out. A precedent has been established; the first man that made a car tested it on the road, and the mere fact that everybody is doing it seems to show that some test is necessary.

HERBERT CHASE:—It takes, as a rule, at least half a day to set up an engine for a test; whereas with a device like the one described by Mr. Dean it would be possible, probably, to set up within an hour and make a test within another hour.

H. G. MCCOMB:—If the slippage of the tires is so small what is the disadvantage of testing the car with its own tire equipment upon the drums and simply measuring the drawbar pull?

HERBERT CHASE:—There are advantages and disadvantages to that method. The advantage is that it gives very close to the actual power which the car delivers through its tires, the available power which the car has for propelling it over the ground.

H. C. MCCOMB:—And that is what you are interested in, of course?

HERBERT CHASE:—That is the important factor; but there is always present the difficulty that the losses in tires are a very large per cent. of the total losses of the car; probably as high as 20 per cent.; and those losses vary as between different tires at least 50 per cent., possibly 100 per cent. That is, if the loss was two horsepower per tire on one set of tires, it would be four horsepower per tire with another set.

C. F. CLARKSON:—With the same inflation?

HERBERT CHASE:—With the same inflation. With the Palmer cord type, which is a very light. flexible tire, the losses are, of course, very much less than with a heavy tire, which is not nearly so flexible. It would be possible, in fact, to drive through solid tires. But the chief use of an apparatus in factory tests is to get away from the tire losses and the tire wear. Tire wear takes place driving on the drums as well as on the road, although probably not to as great an extent. The drums used in the old equipment at the club there were made of paper. In extensive tests which Professor Riley conducted in the summer of 1908 he came to the conclusion that the tire slippage, even under the worst conditions, was probably not in excess of 4 or 5 per cent. It is practically impossible, however, to measure the exact slippage of the tires, for the reason that what you might term the rolling circumference of the wheel is continually varying, and it is, therefore, impossible to compute the distance that a point on the tire travels in one revolution.

N. B. POPE:—Then, as I understand it, the main cause of the variation

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in tire loss was the difference in the structure of the different tires they used to send out.

HERBERT CHASE:—Precisely.

A MEMBER:—What inflation?

HERBERT CHASE:—Well, we endeavored in the testing to keep the inflation uniform, or at least to follow the specifications given by the manufacturers for inflation of different sizes of tires. We always measured the pressure of the tires.

M. R. MACHOL:—Before and after the test?

HERBERT CHASE:—Before and sometimes after. Of course, it would increase somewhat on a continued run, but the tests were seldom of sufficient duration to increase the pressure to any great extent. As a matter of fact, it was seldom found possible to run an engine and keep a constant load for more than two or three minutes. It was necessary after the dynamometer was originally installed to put in a blower, which had not been provided in the original equipment. That blower supplied a breeze up to fifty or sixty miles an hour, but was still insufficient to keep the car cooled for more than two or three minutes.

W. P. KENNEDY:—Along this line of road testing I might call attention to a paper that was recently presented at the Electrical Vehicle Association here in New York by Mr. Churchward, showing some results of tests he made on electric cars with specially designed recording apparatus installed thereon. The set of curves accompanying the paper is very interesting as showing the difference in the road surface and varying wind resistance, and also the difference in regard to tires. Tests were made on some electric pleasure cars having pneumatic tires, and some commercial cars having solid tires. The speed was increased very much beyond the speed of electric vehicles by means of increasing the size of the motor and the battery. So the curves give a very wide range. Inasmuch as the data resulting from these tests are very accurate and reliable, they apply to any form of road vehicle, whether gasoline or electric.

HERBERT CHASE:—Of course, an electric vehicle possesses many advantages over a gasoline vehicle in the matter of road testing, because you can get measurements from electric instruments which it is impossible to get from any gasoline car, unless some such device as Mr. Masury spoke of, the Kenerson dynamometer, is used. The amount of power actually in use or put through the tires is very much smaller, I believe, in the case of electric vehicles than of gasoline vehicles.

W. P. KENNEDY:—Due to the speed; but if you bring the speed up to that of gasoline vehicles the power is about the same for the same weight. The accuracy of the determinations makes the set of curves accompanying this record more valuable than a set of gasoline vehicle curves.

PROF. W. C. MARSHALL:—I am more or less committed to road testing, because I have done more of it than I have laboratory testing. When you come to look at the experiments that have been made by Dr. Riedler of Germany you are compelled to express a good deal

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of admiration for the amount of work he has done and the results he has obtained from laboratory tests on rotating drums. The curves that he has plotted from his tests are very conclusive regarding the amount of horsepower that is lost between the motor and the rear wheels and the amount of power that it takes to drive a car. That is, he has tested the rear wheels running under power and then moved the car back and started it on the front wheels and driven the drums from the motor, obtaining the power loss in the front tires simply from the rolling of the tires. That is about 4 per cent., he finds. Now when you come to drive those cars under their own power on the road the loss in the rear tires he made out to be something like 22 to 25 per cent. These two added together show the loss in tires on the road.

Of course in the laboratory you do not have any chance to measure the wind resistance. The wind resistance has been measured so much that our records have been made to show that it does not differ very much. That is, you can take the curve of wind resistance and find where it intersects the horsepower curve obtained in the laboratory and you will find the probable speed of that car on the road. Dr. Riedler did that; then he took a car out—it was a Benz racer, 120 horsepower, I think—and found that it could be run at the speed he figured it could be run from the test which he made in the laboratory.

He has taken into account the friction all through the system, the mechanism between the motor and the rear wheels, and shown the curve of the horsepower, for instance, of the motor; then he has shown the curve of the transmission and of the differential; and the curve at the rear wheels. Placing the available power of the car on the dynamometer you can see just exactly what those losses are. Any one interested in tests of this kind will find they can get a great deal of information out of these tests of Dr. Riedler. I think he deserves a great deal of credit for work that he has done on rear-wheel testing.

A. L. McMurtry:—There are some things that the rear-wheel dynamometer cannot do. First, it cannot give you the rolling of the car. Where you have an electric dynamometer load on the rear wheels you cannot pull out the clutch and have the wheels roll along so you can shift gears with a fixed load on them. The rear wheels will very naturally heat up much more quickly with this load than if they were running along the road.

Second, you cannot get acceleration tests; that is, you cannot jump from a speed of ten miles an hour to a speed of twenty miles an hour and get the actual road conditions.

Third, as has been brought out, you cannot get the movement of the springs, the frame distortion or the action of the steering gear with this dynamometer. You can, however, get a fixed condition. You can take the car out on the road and by a series of test runs with various openings of the carbureter get the speed that car will travel. Now with that same fixed carbureter and the dynamometer holding the car to that speed, you will then get practically a road torque curve. If the fastest

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that car can go on the road is forty miles an hour and you never permit the car on the dynamometer to exceed that speed, you will get road conditions. That means that considerable of the testing can be done on the dynamometer. After that testing is finished a car can be taken out on the road for acceleration test or the shifting of the gears and the action of the clutch.

In regard to the slippage of tires, especially at high speeds, Brooklands Track is quite rough, for the same reason as the Long Island Motor Parkway is rough. It is built in sections, and running at high speeds the jump from one section to another makes it quite rough. It is not the surface that you get on an ordinary road. Mr. Darracq, who, I think, is one of the cleverest racing car designers in the world, was the first to do away with the differential gear in the racing car; the idea being that when one wheel slipped from the road the other wheel would take the full load from the engine and minimize as far as possible the tire slippage.

The trouble with dynamometer testing in factories is that reports of the tests are no better than the man who makes the tests; and some factory superintendents have the idea that if they put in a first-class dynamometer and a fourth-class man they are going to get first-class results. That is one very important factor in all dynamometer testing.

It is my opinion that the rear-wheel dynamometers, such as the one described, handled properly, will eliminate at least 60 per cent. of the road testing.

MR. PERRY.—All the manufacturers, I know of who use these dynamometer tests break in the cars during them and do their adjusting afterwards; that is, they get a maximum from the car on the road test that they do not get on the dynamometer. For breaking in the cars and seeing that the bearings are all right, wearing them in, the rear-wheel dynamometer is a good idea.

P. P. DEAN.—And you believe that it is not necessary at all to take or preserve any rear-wheel measurements?

MR. PERRY.—No.

HERBERT CHASE.—When running on the road you get the torsion and strain on the chassis which tend to throw the bearings out in a way which it is impossible to throw them out in a stand test. But the stand test does serve to run in the gears and it is possible to locate the origin of any undue amount of noise and also easy to locate any undue loss in friction by observing the temperature of the various parts during the tests. But it is necessary to provide some means of cooling the motor either by disconnecting the pipes to the radiator and circulating the water through a tank to which cold water is added, or by using a blower.

M. R. MACHOL.—Approximately what is the variation of drawbar pull of different cars?

HERBERT CHASE.—I do not recall ever seeing a drawbar pull of over seven hundred pounds; that is, at least in all the tests I have made at the club. We never run through all the low gears, because there was not very much to be gained by that.

M. R. MACHOL.—Was that through the low gear?

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HERBERT CHAEE.—I think it was; but that was sufficient actually to pull off little particles of rubber almost large as an eraser from the tires.

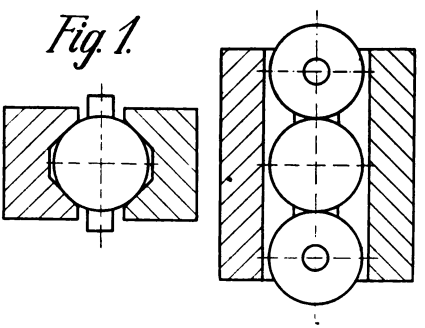
M. R. MACHOL.—That seems strange, because I know on the solid tires the drawbar pull is about ten thousand pounds.

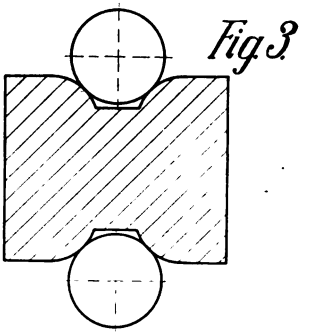
HERBERT CHASE.—A great deal depends on the area of surface in contact with unit pressure. Of course, in actual service you would probably never run into a condition in which you would require seven hundred pounds drawbar pull.

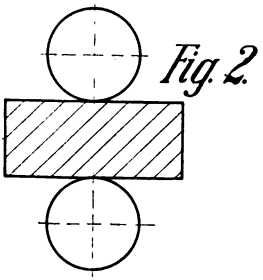
## MOUNTING OF BALL BEARINGS

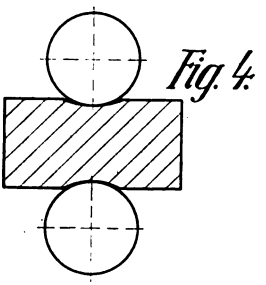
BY A. RIEBE

The way in which the safe load for the balls and races for ball bearings has been found is very well known. Nevertheless, as it is now thirteen years since the experiments in question were completed, it will, perhaps, be interesting to give a short review of the same. Fig. 1 shows the arrangement of the first experiments. Three balls were placed one over the other. By the two guides the centers of the three balls were placed in the same axis. Two little tubes attached to the upper and lower balls carried the mirror apparatus to measure the deflection micrometrically. The balls were loaded by an hydraulic press, the piston of which had no leather gasket, so that no friction absorbed power transmitted from the

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press to the balls. The pressure was controlled by a mercury manometer.

We tested balls of from ⅛ in. diameter to 1⅛ in. diameter. We measured the whole deflection and the permanent set. The result of this experiment is that the safe load varies as the square of the ball diameter.

We continued our experiments to find the form for the races. We were somewhat astonished to learn that the balls are capable of carrying relatively high loads. Professor Stribeck thought that perhaps the surface of the ball offered resistance like in the case of an arch. For this reason he proposed for the first experiments the form of race shown in Fig. 3. We found that we were working in the wrong direction. We tested the arrangement shown in Fig. 2, a flat steel plate being placed between the balls. Later I proposed to test steel plates with a groove as shown in Fig. 4. The safe loads for the same linear deflection were found to be four to five times greater in the arrangement of Fig. 4 than in that of Fig. 2. As we found that the coëfficient of friction is not sensibly higher with races made after the form of Fig. 4 than after Fig. 2, we chose definitely the design shown by Fig. 4.

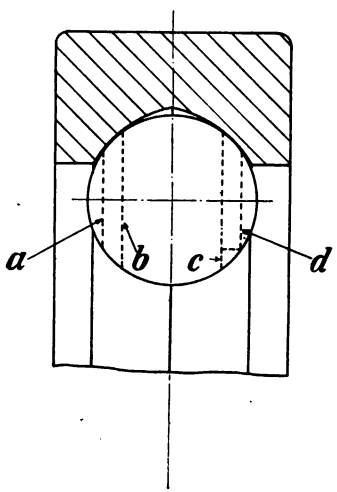


Fig. 5

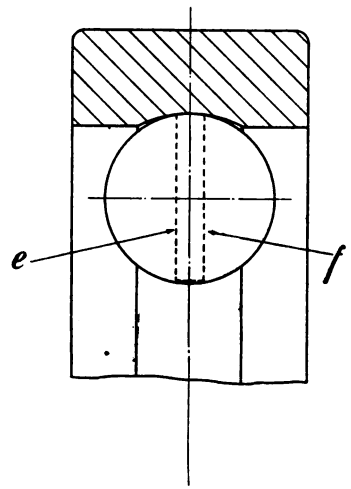


Fig. 6

Using this form, the bearing will not permit of adjustment. The area of contact between the balls and the races is the zone surrounding the equator of the balls. Fig. 6 shows the very well known ball bearing. In Fig. 5 we see the principle of a bearing capable of adjustment. In all designs similar to this it is necessary that the zone of contact be placed between the equator and the poles. The radius and the contact of both ball and race are then very different. You will note the difference between the radius *a*, which limits the zone of contact near the pole, and the radius *b*, which limits the zone on the equator. You will see that the distance *c* is about one-third of the distance *d*, which means that the points at the sur-

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face of the balls surrounding the radius *b* have one-third higher circumferential speed than the points surrounding the radius *a*. Such a difference means that there is a very perceptible sliding between the balls and their point of contact with the races. Sliding under high specific pressure means that there is a movement between the balls and the races like in the grinding machine. For this reason a ball bearing capable of adjustment can never give satisfaction either before or after adjustment.

If the bearings are made as indicated by the experiments before mentioned and of the necessary high-grade steel, with high-class workmanship, they will give satisfaction if fitted in the right way. One of the important points is that the inner race have a tight fit to prevent undue relative movement between the shaft and the inner race. Otherwise the inner race leaves contact with the shaft at the point opposite the direction of the load. In every application vibration is encountered. The phenomena produced under these circumstances are very well known. The shaft shows a trace of rust around the place occupied by the inner race and the inner race itself is also rusted. The space between the inner race and shaft will be increased at every revolution and after a relatively short time the shaft will become worn.

I have heard frequently that the users of ball bearings have been afraid of expanding the inner race in mounting ball bearings because of its having been made of hardened steel. Of course, if the proper grade of steel is not used and if such steel is not properly hardened, their fears are well founded. Under proper conditions bearings can carry and must be able to withstand heavy shocks and severe distortions.

The outer race should always have a piston fit. Where two bearings are used only one outer race should be fixed axially. The other outer race should not be limited at all in the axial direction. This is the only and at the same time the cheapest way to prevent jamming of the ball bearings. Unfortunately this very simple rule has not always been followed. The foreman in the shop gets instructions from the engineer and tells his workmen to give the outer race a piston fit, but "a good piston fit." Then the workmen often give the outer race of the bearing a tight fit.

A further point is to prevent the possibility of dust and water entering. Felt washers are not the right thing to make the housing tight. Felt transports both the grease and impurities from one side to the other by capillary attraction. A gasket made of leather as shown in Fig. 7 gives quite satisfactory results. Small quantities of oil or grease ooze out from time to time but push away all impurities accumulated on the outside of the shaft.

To assure the right fit easily and cheaply it is necessary to have the ball bearings made so accurately as to be interchangeable. The greatest accuracy is required for the bore. When I began to work out the ball bearing series, I experimented with very small tolerances. I found that Professor Schlassinger, then chief engineer of the testing room of Ludwig Loewe, Berlin, now professor at the Polytechnic of Charlottenburg, agreed with me that the limits between the maximum and minimum dimensions should not be smaller than 0.015 mm. The allowance for the

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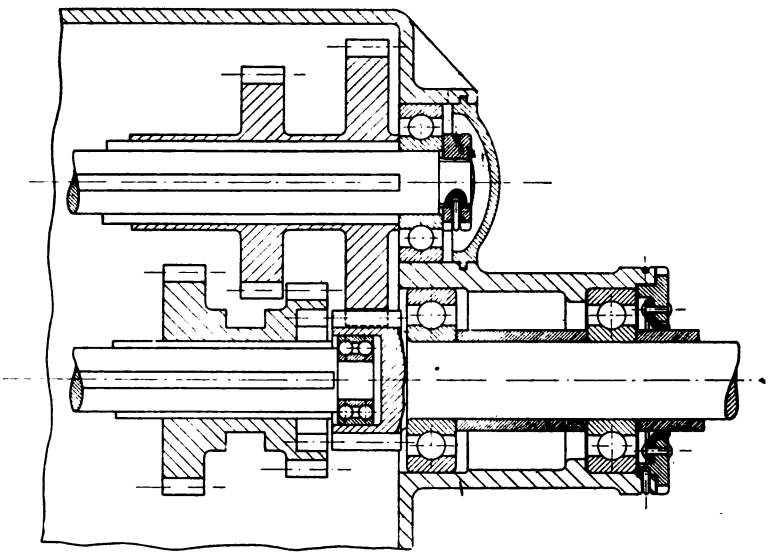

Fig. 7

bore in our workshop is minus 0.01, plus 0.005 mm. The workmen grind the bore until the minimum mandrel will enter, which means the bore in most cases will be some thousandths of a millimeter below the standard size. We test the holes with ball gages in our shop, as it is possible to feel one-thousandth of a millimeter with the ball gage, and further feel if there are grooves or other imperfections in the bore. Our bore is exact and always under the standard dimension. It is never possible to feel such imperfections with a cylindrical gage.

To secure the tight fit for the inner race it is necessary that the shaft be made larger than the bore. The allowance for the shaft increases with the diameter of the shaft (See Table I). To assure a good axial limit for the inner race it is necessary that the integral shoulder or collar be not too small. The diameters of the shoulders are also given in Table I.

In Table II you see the tolerances for the housings of ball bearings. The outer races must always have a piston fit. For this reason the dianmeter of the outer race should never exceed the standard size. To always secure a piston fit in the housing for the outer race, the minus allowance for the housings is zero. This means that the bore of the housing shall never be smaller than the standard dimensions. The necessary tolerance is always taken on the maximum side. You see that the maximum column for the housings begins with plus 0.01 mm., going to 0.025 mm. for housing with a bore over 150 mm.

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TABLE I.—SPINDLE DIAMETERS FOR PRESS FITS FOR INNER RACES, IN MILLIMETERS

| Inner Race Diameter | Minimum Diameter of Shaft | Maximum Diameter of Shaft | Diameter of Shaft at Shoulder |
|---|---|---|---|
| 10 | 10+0.005 | 10+0.02 | 14 |
| 12 | 12+0.005 | 12+0.02 | 16 |
| 15 | 15+0 005 | 15+0.02 | 19 |
| 17 | 17+0.005 | 17+0.02 | 22 |
| 20 | 20+0.005 | 20+0 02 | 25 |
| 22 | 22+0.01 | 22+0.025 | 27 |
| 25 | 25+0 01 | 25+0.025 | 30 |
| 27 | 27+0.01 | 27+0.025 | 32 |
| 30 | 30+0.01 | 30+0.025 | 35 |
| 35 | 35+0.01 | 35+0.025 | 40 |
| 40 | 40+0.01 | 40+0.025 | 45 |
| 45 | 45+0.015 | 45+0.03 | 50 |
| 50 | 50+0.015 | 50+0.03 | 60 |
| 55 | 55+0.015 | 55+0.03 | 65 |
| 60 | 60+0.015 | 60+0.03 | 70 |
| 65 | 65+0.015 | 65+0.03 | 75 |
| 70 | 70+0.015 | 70+0.03 | 80 |
| 75 | 75+0.015 | 75+0.03 | 85 |
| 80 | 80+0.02 | 80+0.035 | 90 |
| 85 | 85+0.02 | 85+0.035 | 95 |
| 90 | 90+0.02 | 90+0 035 | 100 |
| 95 | 95+0.02 | 95+0.035 | 105 |
| 100 | 100+0.02 | 100+0.035 | 115 |
| 105 | 105+0.02 | 105+0.035 | 120 |
| 110 | 110+0.02 | 110+0.035 | 125 |

TABLE II.—TOLERANCE IN DIAMETERS OF BEARING HOUSINGS

ALL DIMENSIONS GIVEN IN MILLIMETERS

| Diameter of Outer Race | Inside Bore of Housing | |
|---|---|---|
| | Plus | Minus |
| Up to and including 50 mm | 0.01 | 0.00 |
| From 51 mm. including 100 mm | 0.015 | 0.00 |
| From 101 mm. including 150 mm | 0.02 | 0.00 |
| Over 150 mm | 0.025 | 0.00 |

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## DISCUSSION

L. G. NILSON:—I would like to ask Mr. Riebe what kind of steel the races are made of and also something about the treatment and hardening of it.

A. RIEBE:—In the beginning of our ball bearing experiments we used what is called at this time crucible tool steel. We hardened the first bearings in a gas furnace fitted with a muffle. We found that this steel did not give satisfaction, as from the slightest presence of sulphur in the flames the races were sometimes a little soft in spots. Then we tested different kinds of steel and found that chrome steel gave a good result. The use of chrome steel, I believe, is now universal with all ball bearing manufacturers. The freer the steel is from phosphorus and sulphur the more useful it is for ball bearings. Nearly 0.80 per cent. carbon is always necessary. About 1.5 per cent. chromium is used—a little less in the steel for the smaller sizes, a little more in the steel for the larger sizes. We make the races from solid steel bars, consisting of not more than .002 per cent. of sulphur and less than this of phosphorus; no traces of manganese and no traces of silicon. This is the best steel for ball bearings, but this analysis is good for nothing if the steel is not homogeneous, and for this reason it must be made from the best minerals. The balls and ball races must be made from material which it is possible to harden throughout. We, like a good many ball bearing makers, heat our races in a salt bath, so that it is absolutely impossible to overheat the skin. Of course, it is a very important point to prevent overheating, as otherwise the material loses its elasticity.

F. J. JAROSCH:—Is it necessary to have the same tolerance for all sizes of bore, or is it better to have varying tolerances for different sizes of bore?

A. RIEBE:—I think it is well to have the same small tolerance for larger bores. There may be difficulties in production, but it is easier for the users of the ball bearings.

F. J. JAROSCH:—I understood you to say before that the man on the machine will always grind the bore so that the minimum gage just fits, so that all bearings will be a little under standard, never plus, at the bore.

A. RIEBE:—Quite right, sir.

F. G. HUGHES:—I think that all the ball bearing representatives here owe Mr. Riebe a vote of thanks for bringing up the points which he has in regard to the correct mounting of bearings. The question of not stretching the bore on the shaft too much where it is too small, and the question of mounting the outer race so that it may creep, as we call it, need emphasis. End shake in the bearings is a point of considerable moment. In this country we have found that most engineers desire a bearing which has that singing sound which is not good for a bearing. The bearing should have a small amount of end shake; otherwise in pressing on tapered shafts, as has been mentioned, the inner race will be extended, the balls will be compressed, the races will be under undue pressure and in running we will have a condition where the bearing can never recover from the stressed condition; in other words, failure from fatigue. All of these points are exceedingly valuable.

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# INDEX


PAGE

Aluminum alloys ..... 322
Atmospheric changes and variation of power.....183, 328
Ballbearings Division Report held over.....2, 64
mounting ..... 363
pioneer tests ..... 363
Bibliography of Steel ..... 41
Bolt equipment for flanges for solid tires..... 54
Brakes, position of on motor trucks..... 263
Broaches Division, situation in..... 70
Car design, influence of sales department..... 236
Carbon steels, notes on ..... 9
physical characteristics ..... 36
Carbonization of motor cylinders .....260, 321
Carburetion, discussion of ..... 201
kerosene ..... 306
problems ..... 192
Cast steel wheels for trucks.....286, 287, 289, 293
Chassis testing apparatus ..... 346
Chromium steels, notes on ..... 26
Chromium vanadium steels, notes on ..... 26
physical characteristics ..... 39
Clearance in motor cylinders ..... 261
Cold test of lubricating oil ..... 257
Combustion efficiency ..... 176
Commercial automobiles, depreciation of ..... 108
Commercial Car Wheels Division, fourth report of, as accepted..... 31
discussion of....54, 66
Compensating carbureter ..... 195
Constant carbureter mixture .....201, 205
Couple-gear truck wheel practice ..... 283
Crankshaft design, six-cylinder ..... 173
Cylinders, clearance of motor ..... 261
Depreciation of commercial automobiles..... 108
Design, influence of sales department ..... 236
some factors of motor ..... 166
Desirable number of gear changes ..... 336
Drop forged wheels for trucks.....99, 278, 282
Efficiency of tires ..... 222
Election of members, tellers' report of ..... 58
Electrical Equipment Division Report .....2, 67


Digitized by Google

PAGE

Engine lubricating oil ..... 254
Engineering department's relation to sales department..... 236
Fabric for tires ..... 214
Fan dynamometers ..... 110
Felloe band of S. A. E. truck wheel standard.....31, 54, 66
Fillers for tires ..... 215
Fire test of lubricating oil ..... 256
First pneumatic tire, J. B. Dunlop on..... 216
Flash test of lubricating oil ..... 256
Friction loss curve, engine ..... 171
Gages in factory inspection..... 141
Gasoline, expressing density of ..... 176
Gasoline-electric omnibus running costs ..... 87
Gear changes, desirable number of..... 336
General inspection methods ..... 136
Heat balance ..... 176
Heat treatment of leaf springs ..... 248
Heat treatments, list of ..... 32
Horsepower curves ..... 172
measurement ..... 110
variation with atmospheric change .....183, 328
Ideal automobile plant ..... 297
Illumination of omnibuses .....93, 102
Inspection methods .....136, 299
Instructions for care of storage batteries.....2, 69
Insulation requirements of electrical equipment of gasoline cars..... 68
Iron and Steel Division, fourth report of, as accepted.....7, 59
discussion of .....47, 59
Iron castings, notes on ..... 31
J. B. Dunlop on first pneumatic tire ..... 216
Jackshaft versus rear-wheel brakes..... 263
Kerosene carburetion ..... 306
Leaf springs, heat treatment of ..... 248
Limits, general inspection ..... 137
Locomobile truck wheel practice ..... 280
London General Omnibus .....75, 91
London motor omnibus service ..... 75
Long-stroke motors .....169, 178
Lubricating oil, engine ..... 254
Malleable iron castings..... 148
wheels for trucks..... 282
Manifold design ..... 320
Measurement of horsepower ..... 110
Metal wheels for trucks ..... 276
Miscellaneous Division, matters in hands of..... 71
Mixing valve ..... 195
Monument to the late President Donaldson..... 375

Digitized by Google

PAGE

Motor design, discussion of ..... 177
some factors of ..... 161
test chart ..... 175
lubricating oil ..... 254
Motor Testing Division, work of ..... 70
Mounting of ball bearings ..... 363
Multiple-jet carbureter ..... 197
Nickel chromium steels, notes on ..... 20
physical characteristics ..... 37
Nickel chromium vanadium steels, notes on ..... 26
Nickel steels, notes on ..... 16
physical characteristics ..... 37
Nomenclature Division, worldwide coöperation being arranged ..... 71
Notes and instructions on steels ..... 8
Officers of the Society ..... 369
Omnibus illumination ..... 93, 102
Omnibus service in London ..... 75
One- and two-wire electrical installation on gasoline cars ..... 67
Orifice, variable fuel ..... 197
Packard inspection methods ..... 136
truck wheel practice ..... 279
Paris omnibus operation cost ..... 87
Petroleum, different kinds of ..... 262
Physical characteristics of malleable iron ..... 154
of steels ..... 36
not to be combined with chemical specifications ..... 8, 48
Pleasure Car Wheels Division, status of pneumatic rim standardization 70
Pneumatic rim standardization ..... 6, 70
Pneumatic tires ..... 208
discussion of ..... 216
efficiency ..... 222
rims for ..... 216
President Marmon announced as honorary member of the Institution of Automobile Engineers ..... 57
Presidential address ..... 57
Rims for pneumatic tires ..... 216
Road tests of chassis, versus stand test ..... 346
Rubber supply ..... 210
Sales department's influence on design ..... 236
Screw stock, notes on ..... 15
Sections of the Society ..... 370
Self-aligning test specimen for use with hard steels ..... 161
Silico-manganese steel, notes on ..... 30
physical characteristics ..... 40
Six-cylinder crankshaft design ..... 173

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PAGE

Solid tires, bolt equipment for flange ..... 54
wheel dimensions for ..... 53
Souvenirs, list of presented to British guests of the Society ..... 302
Spokes, number of for wood truck wheels ..... 286
Stand testing of chassis ..... 346
Steam omnibuses ..... 91
in America ..... 107
Steel, bibliography of ..... 41
Steel castings, notes on ..... 16
Storage batteries, instructions for care of ..... 2, 69
size and capacity of ..... 69
Structural steel wheels for trucks ..... 99, 283, 285
Tellers of election of members, report of ..... 58
Test specimen for use with hard steels ..... 161
Testing, chassis ..... 346
motor ..... 174
Thermal efficiency ..... 176
Tire fabric ..... 214
fillers ..... 215
wear on metal wheels ..... 287, 292
Tolerances of S. A. E. truck wheel standard ..... 31, 54, 66
Treasurer's report ..... 58, 304
Truck brakes, position of ..... 263
Standards Division report ..... 1, 65
wheel standards ..... 31, 54, 66
wheels ..... 272
Valve metals, notes on ..... 31
nickel steel for, eliminated from, specifications ..... 47, 60
Viscosity test of lubricating oil ..... 256
Vulcanization ..... 213
Water injection to motor ..... 318, 330
Wheel dimensions for solid tires ..... 53
Wheels, motor truck ..... 272
Wire wheels ..... 223
discussion of ..... 228
Wood wheels for trucks ..... 273
number of spokes ..... 286
Worm gears ..... 106
Yield point and elastic limit ..... 8, 9, 48

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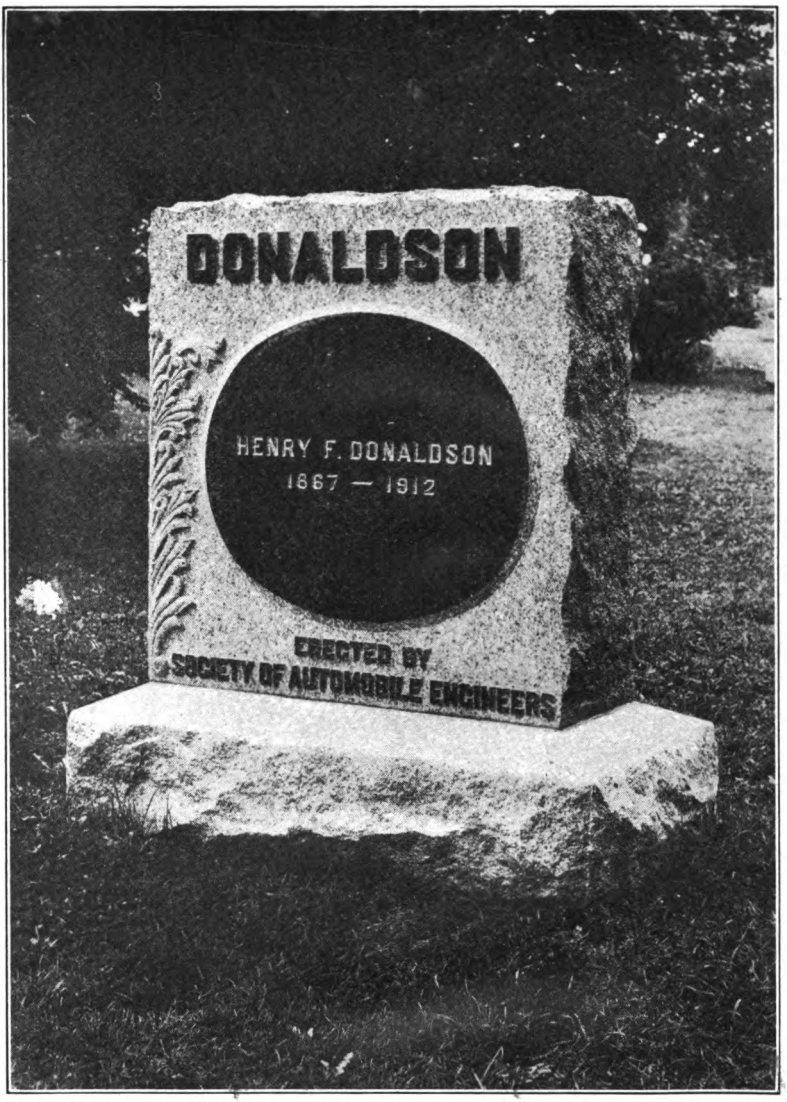


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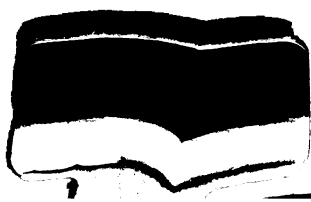

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